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SAFETY *in the* HANDLING *and* USE *of* EXPLOSIVES

INSTITUTE OF MAKERS OF EXPLOSIVES

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SAFETY *in the* HANDLING *and* USE *of* EXPLOSIVES

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PREFACE

THE majority of accidents that occur with explosives could be prevented and the aim of this book is to help prevent them. The methods recommended for handling and using explosives do not represent the ideas of any one man, or group of men—unless the field men of the different companies constituting the Institute of Makers of Explosives can be called a group—but are the result of years of study and the combined experience of many men engaged in the use of explosives in practically every type of work.

Much more detailed information is given here than is possible in Safety First posters or the leaflets that are inserted in dynamite cases. As certain precautions are common to many different blasting operations, there is some repetition, but it seemed more advisable to repeat these injunctions than to leave them out when dealing with any one class of work.

The Institute of Makers of Explosives is indebted to Mr. Daniel Harrington, of the United States Bureau of Mines, for many valuable suggestions which are incorporated in this edition.

It is the earnest hope of the Institute of Makers of Explosives that this book will aid consumers of explosives in their efforts to conduct their blasting operations with safety.

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SAFETY in the HANDLING and USE of EXPLOSIVES

TRANSPORTATION

The consumer's responsibility for the safe handling of explosives begins with the arrival of a carload shipment on his own railroad siding or with the transfer of the explosives into his possession from a car on the railroad company's tracks, or from the manufacturer's or dealer's magazine, or from the manufacturer's or dealer's truck. In the case of carload shipment, an inspection should be made on the arrival of the car to ascertain whether its contents are in proper condition.

Occasionally, rough handling in transit may telescope cases or break them open so that there will be loose explosive between cases or on the floor. If inspection reveals such a condition in a car of high explosives, the workmen who are to unload the car should be warned to avoid every chance of friction against the loose explosive that might cause an explosion in the car.

Especial care should be used in handling damaged cases which should be carefully removed from the car and away from car door. If condition of cases is such that they can be safely repaired, the explosives should be temporarily removed and necessary repairs made (using only wooden tools). Then replace explosives in case (including any unbroken cartridges that may have been spilled on car floor), being careful that lining paper is intact and that at least $\frac{1}{4}$ inch of dry sawdust is under cartridges, also that no nails protrude into interior of case to come in contact with explosives.

A case that contains any explosive and is so damaged that it cannot be repaired should be reinforced by stout wrapping paper and twine, placed in another strong box and surrounded by dry sawdust, or dry and clean cotton waste or newspaper wads.

As the unloading of car proceeds, any loose explosive on car floor should be immediately swept up and placed in a receptacle. After the unloading is completed this loose explosive, together with any broken parts of cases remaining, should be disposed of by burning, observing the following precautions:

"The burning ground selected should be in a safe location (if possible 1,000 feet from any dwelling, public road or railroad) at a point where it will not start a brush fire and where, in the event of its exploding while burning, it will do no damage to surrounding property. If there are broken cartridges, they should be opened and contents, together with sweepings from car floor, spread thinly on a few sheets of paper or on excelsior laid on the ground. Do not pile in any quantity. To insure explosive burning properly, pour a little kerosene over it. Then provide a fire train from the explosive to a point several feet distant, consisting of a small quantity of straw, paper, excelsior, or similar material, lighting the fire at the end of the train farthest from the explosive, then retiring to a point several hundred feet distant until explosive is burned. Do not use the same spot for burning a second lot. All residue remaining after burning the explosive should be buried in a hole and covered, to prevent livestock coming in contact with it. Broken case parts should be burned separately but in a similar manner."

In the event of damage to packages of black powder, in either granular or cartridge form, any loose powder or kegs unfit for use should be destroyed by sinking them in a body of water. Keep loose powder out of the way of workmen's shoes while working in car; and after unloading is completed, thoroughly sweep car floor and saturate it with water.

The danger of starting an explosion in a car of black powder, whether granular or pellet, would be in sparks or fire, or in friction which might cause sparks or intense heat. In unloading a car of any kind of explosives they should always be protected from sparks from passing engines.

Men should never smoke while handling explosives or working in close proximity to them. This applies not only to unloading but to every stage of the handling of explosives in the course of transportation, distribution and blasting. Cases or kegs containing explosives should always be lifted and set down carefully, never slid over one another nor dropped from one level to another.

The vehicle provided to transport explosives from the railroad car or manufacturer's or dealer's magazine to the consumer's magazine should be strong and substantial and in good working order. A closed body is best. If an open bodied vehicle is used, the ends and sides should be high enough to prevent packages of explosives from falling off and the load should be covered with a fire-resisting tarpaulin. The floor should be of wood and any metal in the body likely to come in contact with cases or kegs should be covered with wood or other non-sparking material.

The batteries and wiring on motor vehicles for transporting explosives should be located so that they will not come in contact with the packages of explosives and all wiring should be completely insulated and securely fastened so as to prevent short circuiting and fire.

The truck should be equipped with not less than two fire extinguishers of a make approved by the National Board of Underwriters, located at convenient points, filled and ready for immediate use. To reduce fire hazard and risk of explosion, the chassis, engine, pan, and the bottom of the body should be kept free from surplus oil and grease.

Where state laws or local ordinances prescribe special markings for vehicles transporting explosives, same should be complied with. Where no such regulations exist, such vehicles should either be placarded on each side and the rear with the word "EXPLOSIVES" in letters not less than 3 inches high or display a red flag 24 inches square marked with the word "DANGER" in white letters not less than 6 inches high.

A truck used for transporting explosives should be inspected daily in order to determine that—

Fire extinguishers are filled and both extinguishers and equipment are in good working order,

Electric wiring is completely insulated,

Chassis, engine, pan and bottom of body are clean and free from surplus oil and grease,

Gasoline tank and feed line have no leaks,

Brakes and steering apparatus are in good order, and that—

Truck is in proper condition in all other respects for handling explosives.

A truck should never be loaded with explosives beyond the truck manufacturer's rating, nor should packages of explosives be placed in such a position that they may fall off.

No metal, metal tools, carbides, oils, matches, firearms, electric storage batteries, inflammable substances, acids or oxidizing or corrosive compounds should be carried in the bed or body of any vehicle transporting explosives.

Bale hooks or other metal tools should never be used for loading or unloading explosives.

When transporting explosives, the truck should be driven by and be in charge of a driver who is careful, capable, reliable, able to read and write the English language, and not addicted to the use of intoxicants or narcotics. He should never smoke while on or near the truck, nor carry matches, firearms or loaded cartridges. He should be familiar with road rules and also with the state laws and the local ordinances and regulations governing explosives in the cities or other municipalities in and through which it is necessary to travel or pass and should comply with them. He should have the truck always under complete control and should never allow it to coast down hill. He should, of course, be familiar with the proper manner of handling explosives.

Unauthorized persons should never be permitted to ride on trucks transporting explosives.

When transporting explosives, the truck should come to a full stop before crossing any railroad track and should not attempt to cross the track until it is known that the way is clear and that a train or engine is not approaching.

The gasoline tank of a motor truck should not be filled while explosives are on the truck except in emergency and then only when the engine of the truck is stopped.

A truck containing explosives should never be left without first stopping the motor and securely setting the brakes. When transporting explosives over the highways, it is advisable to avoid unnecessary stops. Stops for meals should be made at some wayside restaurant and the truck should be left well away from traffic and parked vehicles. A truck containing explosives should never be taken into a garage or repair shop.

Explosives should never be left unless they are placed in a magazine and the magazine is locked, or are delivered to some one authorized to receive them. In unloading, packages of explosives should never be piled immediately back of the exhaust as a spark may start a fire and cause an explosion.

It is safer to transport explosives in daylight. If lights other than the truck lights are necessary, only an approved type electric flashlight or an electric lantern should be used.

Primacord may be shipped by freight and American Railway Express without restrictions, except that it shall not be packed with blasting caps or high explosives.

STORAGE

Magazines for the storage of high explosives should be bullet and fire resistant, weather proof, dry and well ventilated. They may be of brick or sand filled construction or of the portable iron type; however, if a portable iron magazine is used, the building should be made bullet resistant by lining with either brick, sand or a weak cement mortar. The magazine should be ceiled and painted with aluminum paint to reduce the temperature in the building.

If there are state or local laws specifying the location of magazines, they should be complied with. In the absence of any laws, it is recommended that all magazines be located in compliance with the American Table of Distances which specifies the distances that magazines containing various quantities of explosives should be located from inhabited buildings, highways and railroads.

The storage of explosives has a much deeper relation to safety in their use than is commonly realized. Improper storage of explosives, detonators, fuse and squibs leads directly to misfires and to the incomplete detonation which leaves unexploded dynamite in the bore hole or thrown out among the blasted material, and to the burning of charges in the bore holes. Even a small leak in a magazine roof may allow a few cartridges of explosives to become wet and the use of these cartridges may result in either misfire or incomplete detonation. A dilapidated magazine, or a magazine with floors close to wet ground, or any condition of storage which would expose ammonium nitrate explosives—and these include all of the extra dynamites and most of the permissibles—or blasting caps, or safety fuse, or squibs to moisture is almost sure to result in one or both of the aforesaid troubles.

Inadequate ventilation of magazines may also lead to misfires or incomplete detonation, for unless air circulates freely through a magazine the atmosphere may become hot and humid, and long exposure to such atmosphere has much the same ultimate effect upon ammonia explosives, blasting caps and fuse as has dampness. With nitroglycerin explosives, it tends to cause a separation of the nitroglycerin from the other ingredients, or a leakiness, that makes the explosives much more sensitive and hence dangerous to handle.

If a steel magazine is used without protection of some kind from the direct rays of the sun, there is danger that the steel will absorb so much heat as to cause ammonia explosives inside to become hard and insensitive. Especially is this likely to happen in a climate of hot days and cold nights where the explosives are subjected to repeated alternations of high and low temperatures. Numerous instances are on record of misfires and partial detonations due to just this cause. A steel magazine for the storage of ammonia explosives in a region of hot sunshine should be ceiled or protected by a wooden roof supported so as to leave free circulation of air between it and the magazine, and by a coat of aluminum paint on the roof, at least.

Primacord should be stored in a cool, well-ventilated magazine. The explosive core of Primacord (P.E.T.N.) has a melting point of 280 deg. F. and therefore should not be stored near steam pipes, stoves or a high degree of heat as the temperature sufficient to melt P.E.T.N. will result in failures. In high summer temperatures the asphalt waterproofing may exude through the exterior wax coat, causing a speckled or mottled appearance. This condition in no way affects the detonating qualities or efficiency of the Primacord.

If fuse is stored in a damp place, it may absorb enough moisture to retard its burning speed. Even if the fuse is redried before using it may be found that the burning speed has slowed down, and worst of all, has become irregular. This irregularity tends to increase the chances of misfires and of the spoiling of rounds due to charges exploding out of their regular order. This latter may result in cutting off the bore holes, leaving the bottoms filled with unexploded powder.

If fuse is stored in a hot place, the waterproofing may become soft and sticky and may strike into the powder train, damaging the powder so that it will not burn; or too much heat may dry out the waterproofing so that it will crack and render the fuse useless for damp or wet work.

If fuse is allowed to come into contact with grease, oils, paints, gasoline, kerosene, distillates and similar solvents, these substances may penetrate the powder core and cause it to fail to burn or to burn with irregular speed.

The handling of misfires and the existence of undiscovered misfires or of unexploded dynamite in the bottoms of holes, or in the broken material, constitute some of the chief sources of accident from explosives. Likewise, incomplete detonation or a burning charge underground may cause fatal accidents, for the gases given off by such shots are extremely poisonous. For all these reasons it is imperative to prevent deterioration of explosives, detonators and fuse in storage, and dry, well-ventilated and reasonably cool magazines are essential to safety in the use of explosives.

The Institute of Makers of Explosives is always willing to furnish plans and specifications for the construction of magazines and to advise concerning their location, if requested.

TRANSPORTATION FROM MAGAZINE TO WORKING FACE

The transportation of explosives and detonators from the main storage magazine to the bore holes involves many problems of safety which vary with all the varying conditions at different operations. Certain general principles will be stated first and then some of the ways and means of applying these principles will be discussed.

First, explosives and detonators should be kept apart until the last possible moment. Whenever feasible, they should be transported in separate conveyances or be carried by different men. If both must be transported in the same conveyance, or be carried by the same man, they should be placed in separate insulated containers.

Second, high explosives and detonators should always be carefully and not roughly handled, protected against shock and friction.

Third, all explosives and detonators should be protected from fire, flame or sparks.

Fourth, they should be protected from moisture.

Fifth, wires of electric detonators should be kept from contact with stray electricity, or other sources of electric current.

Explosives and detonators may be hauled on separate trips, or detonators may be carried into the mine by shot-firers. A type of powder car being used today by some coal mines which seems reasonably safe has two separately insulated compartments, a larger one, opening from the side of the car, for explosives, and a smaller one, opening from the end of the car, for detonators.

The safest way to haul a powder car into a drift mine or from the foot of the shaft in a shaft mine is to shut off all electric power and haul the car by mules or push it by hand. If the car is hauled by an electric motor with an overhead trolley, it should be separated from the motor by two or three empty cars so that sparks from the trolley can not fall on it. It should be attached to the preceding car by an insulated coupling. The powder car should never be attached to a man trip, nor immediately precede nor follow it. If both are in motion at the same time, in the same split of air, their relative position should be such that the air current will be passing from the man trip toward the powder car so that, in case of explosion in the powder car, the flame, smoke and fumes will be carried away from the men, not toward them. The best plan is either to send the powder car into the mine between shifts or to have it precede the man trip by sufficient time to reach its destination before the man trip leaves the outside.

The powder car may deliver explosives and detonators to separate underground distributing magazines, where these are permitted, or to the various sections of the mine, or, in case men's individual containers are filled on the surface and hauled in the car, the men may claim these directly from the car at some central station underground. To facilitate this, each man's container should be marked with his check number. If underground distributing magazines are used, the two should be located at such a distance from each other that an explosion in the one magazine would not be communicated to the other magazine. Furthermore, they should be so located relative to working places and exits as to minimize the danger in case of an explosion. Both magazines should be fireproof and be kept locked. They should be well ventilated to keep the atmosphere dry and, if lighted by electricity, wires should be enclosed in substantial grounded conduits and lamps should be of the double bulb, vapor proof type, preferably set in the walls with screen protection. They should never contain more than one day's supply of explosives or detonators at a time, and they should be kept clear of all empty boxes, papers and refuse of any kind.

Miners should be equipped with non-conductive boxes or bags in which to carry explosives to their working places and no explosive should be issued to a miner unless he brings such a container to receive it. If the miner does his own shooting, he should also have a separate, non-conductive container for detonators.

If shot-firers are employed, as in many coal mines today, they usually carry the detonators into the mine—only the explosives being sent in by powder car—and should, of course, have non-conductive, waterproof containers. A very satisfactory type of container for electric detonators consists of a canvas belt with compartments for individual detonators which is folded and placed in a leather case with lock and carrying strap.

A record should be kept at the distributing magazine of all explosives and detonators issued to miners and shot-firers. Any powder or detonators left over at the end of the shift should be returned to the magazine at the end of the shift by miner or shot-firer and this should be issued to him again on his next shift. If any part cartridges remain at the end of the day they should be left in a moisture-proof container and used the next day.

If explosives and detonators are not sent into the mine in special powder cars, it becomes necessary to provide safeguards for their transportation by miners and shot-firers. If the latter are employed, they generally carry the detonators and the miners the explosives. Sometimes the shot-firers carry both explosives and detonators. If miners do their own shooting, they carry both. The same safety regulation should be enforced under all these conditions, namely, that explosives and detonators be carried in separate non-conductive cases. For men to carry blasting caps or electric blasting caps in their pockets is a not uncommon but highly dangerous practice. Every available means should be used to prevent it.

The next problem of safety that arises is—and this applies particularly to coal mines—what the miner shall do with explosives after they reach his working place and before they are loaded in the bore holes. Where the explosive is delivered in the case, probably the safest method is to open the case and place the cartridge in a wooden box provided for the purpose at a considerable distance from the face, and lock the box. Explosives taken into the working place in a carrying container can be locked up in such a box, container and all, or the container can be placed in a cubby-hole cut in the rib of a crosscut. If the miner has detonators, these should be locked up in a separate storage box or put in a cubby-hole, either one being at least ten feet distant from the box or cubby-hole for explosives. All such cubby-holes should be at least six feet distant from the track and from trolley wires. To leave explosives or detonators lying on the floor where they may be stepped upon, or run over, or struck with tools or may come in contact with electric currents is inexcusably careless and invites disaster.

The disposition of explosives and detonators left over at the end of a shift has a very important bearing on safety. Aside from the danger that if left in the mine they may be accidentally exploded, as by a fall of rock, for example, there is also the hazard that explosives, detonators, fuse or squibs which have absorbed moisture from the mine atmosphere will cause misfires, or they may remain until the pillars are pulled and then be shipped with the coal. If at all possible, left over explosives, detonators, fuse and squibs should be returned to the distributing magazine. If they must be left in the working place, they should be placed in a moisture proof container and this locked up in a wooden box. Of course, explosives and detonators should never be left in the same container or in the same box, unless the box is so constructed that an explosion of caps in one compartment cannot detonate dynamite in the other end.

It is also of importance for safety that any explosives or detonators left after a blast in outside work has been loaded or after secondary shooting has been completed for the day should be returned to the magazine and the magazine locked. Every year a number of persons, generally children, are injured or killed by playing with dynamite or blasting caps which they have found around some mine, quarry or construction project, either lying on the ground or in an unlocked building. These accidents are all due to carelessness on the part of users of explosives. They would not occur if dynamite and detonators were not left where children could find them.

A dangerous practice to be avoided is delivering the entire load for a deep well drill hole or a sprung hole at one time. Fatal accidents have been caused by the fact that when a premature explosion occurred during the loading of a hole there were large quantities of dynamite stacked around the collar of the hole and that these were exploded by the premature detonation in the bore hole. It is a good rule to deliver the proper number of cases of dynamite for each hole at a point at least 100 feet back of the hole, certainly not less than 25 feet, open them there, take one case up to the hole at a time and return the empty case and lining paper to a waste pile. In this way the one case being loaded will be the only one near the collar of the hole at any time and box covers with nails in them and slippery lining paper will not be strewn on the ground around the collar of the hole. Some blasters feel that still greater safety is gained by keeping this one case being loaded 6 feet back from the hole and having one man hand cartridges from it to the man who drops them in the bore hole.

In underground operations a distributing magazine is often necessary near the mouth of the mine. This should conform to the same general standards as main storage magazines. In particular, the same distributing magazine should never be used for both explosives and detonators and the temptation arising from the convenient location of a distributing magazine to allow tools, carbide, oil and other supplies to be kept in it should be rigorously guarded against. A distributing magazine should never contain more than one day's supply of either explosives or detonators.

Whether the operator provides haulage into the mine for explosives and detonators or whether they are carried in by the men depends upon local conditions, but, whatever the system employed, it should be safeguarded as closely as possible. In the former case, explosives should be hauled in a covered, insulated powder car, or if covered, insulated boxes are provided to hold the miners' individual insulated containers, these boxes may be hauled in an ordinary mine car. Various satisfactory types of insulated powder cars are in use. The body of the car may be built entirely of wood, the different sections being put together with wooden pegs instead of nails, or it may be of wood lined with sheet asbestos or rubber, or of metal lined with wood with all nails or screws countersunk so that there is no exposed metal whatever. The body of the car may consist of a single compartment for carrying explosives or it may be divided into small compartments for the miners' individual powder boxes or bags.

OPENING CASES OF EXPLOSIVES

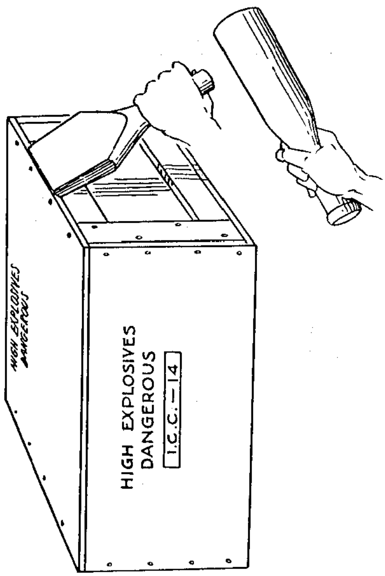


Fig. 1

The opening of dynamite boxes is itself an operation that should be performed with due care. Dropping dynamite cases to burst them open is both inefficient and dangerous. Whether one case is to be opened or a thousand cases, safety demands the use of wooden tools without any metal whatever about them. Any kind of metal tool—hammer, sledge, chisel, shovel, pick, drill steel—may strike a spark from the nails that may cause the dynamite to explode. While it is true that many dynamite cases are opened every year by means of metal tools without accident, it is likewise true that the hazard is always present, and any workman who uses a metal tool for this purpose is exposing himself to possible injury or death. Wooden tools do away with this hazard and they are just as effective. It takes a little forethought, perhaps, to have them at hand when needed, but the prevention of accidents is worth some effort. Any wooden wedge and mallet will serve. Figure 1 shows a dolly and a wedge with a handle which are provided at one large operation for opening all dynamite cases, either lock cornered or cleated.

Figures 2, 3, 4 and 5 show a method of opening lock cornered dynamite cases which combines several safety advantages with ease and quickness. The implements needed are a sharp hardwood wedge and a mallet. The procedure is as follows:

First, stand the box on end, place the edge of the wedge on one corner at the third dovetail from the top and strike the head of the wedge a sharp blow with the mallet. This will start a split in the box from this corner, as shown in Figure 2. Next, repeat the operation on the opposite corner of the same end, as shown in Figure 3. This will usually carry the split around the box so that a slight pull will re-

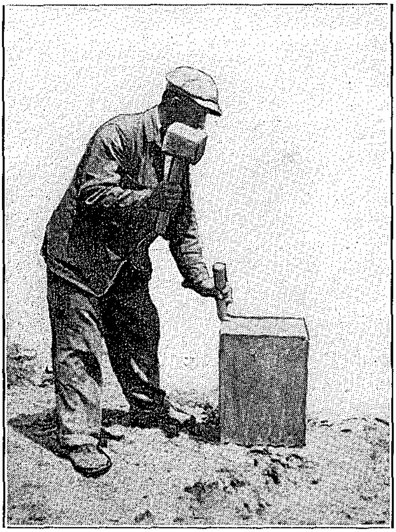


Fig. 2—In another method one sharp blow is struck on one corner at the third dovetail from the top.

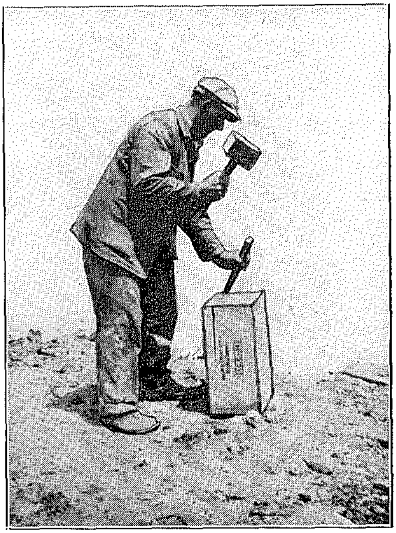


Fig. 3—Next, a second blow is struck on the opposite corner in the same position.

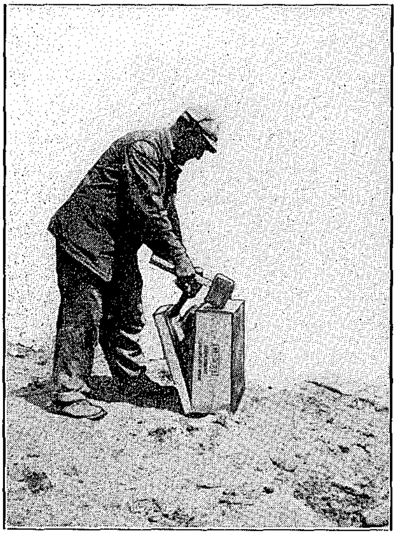


Fig. 4—These two blows carry a split around the box a few inches from the top.

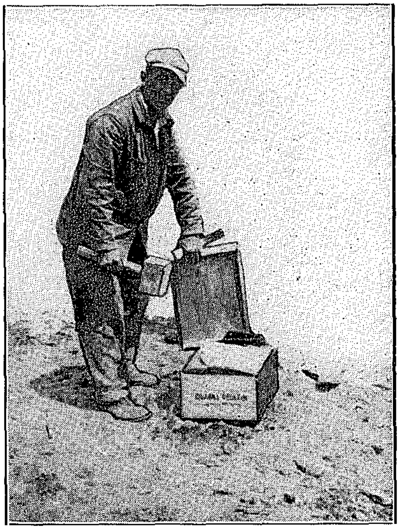


Fig. 5—A slight pull then removes the top of the box intact.

move the lid intact, with the strips of the sides and ends containing the nails attached, as in Figures 4 and 5.

The success of this method of opening cases depends somewhat on the straightness of grain in the wood of the case, but ordinarily the top will split off clean with very little splintering and when a workman gets the knack, it is much faster than other safe methods. Of course the box is spoiled for some future purpose but there is still plenty of it left for carrying stemming material, which is the chief use to which empty boxes are put. For this last purpose, it is much safer to have no protruding or bent nails around the edge of the box.

Opening cases in this way lessens the work of clearing away the tops and reduces the hazard that workmen will be injured by handling splintered boards or stepping on boards with nails in them.

Boxes containing pellet powder should be opened in the same manner as is recommended for opening dynamite boxes. This applies also to grain powder when packed in bags and wooden cases.

Blasting powder kegs should be opened by inserting a wooden wedge under the lugs holding the bung and prying the lugs up. The bung can then be removed.

MAKING AND HANDLING PRIMERS

The proper making and careful handling of primers is of first importance for safety in blasting. As a detonator exerts its greatest force straight away from its charged end, the first principle of priming, both for efficiency and safety, is that the long axis of the detonator should lie as nearly as possible in line with or parallel to the long axis of the cartridge.

PRIMING WITH CAP AND FUSE

In making a primer with blasting cap and fuse the fuse should always be handled carefully so that it will not be sharply bent or abraded in any way and the cap should be handled gently to avoid accidental explosion. The fuse should be cut square across and seated firmly against the explosive in the cap and the cap should be crimped securely on the fuse. Loose crimping may result in misfires or delayed shots. In a specific case where delayed shots occurred, it was found that the fuse was being pulled from loosely crimped caps, leaving considerable space between the end of the fuse and the cap, which remained embedded in the explosive. The primer cartridge was in the middle of the charge. When the fuse spit, it ignited the adjacent explosive and this burned until the flame reached the cap and detonated it. In some experiments simulating these conditions the interval of time between ignition and detonation varied with the distance between the fuse end and the embedded cap, this interval varying from fifteen to fifty minutes.

For wet work, the joint between cap and fuse should be waterproofed with soap, wax or one of the special cap sealing compounds. No substance containing oil should be used for sealing a cap as the oil will injure the fuse.

Figure 6 shows a cartridge primed with cap and fuse by a widely used method known as "lacing." This method of priming is undesirable for several reasons.

(a) If the fuse side spits into the explosive it may cause the explosive to burn.

(b) Nearly all fuse has waterproof coverings around the powder train to protect it from moisture. In cold weather, any sharp bend has a tendency to fracture the waterproofing so that water may penetrate into the powder train and cause a misfire.

(c) Tamping tends to compress the cartridge and thus to make the bends in the fuse sharper, breaking the fuse coating and exposing the dynamite to the side spit of the fuse and the powder train to moisture.

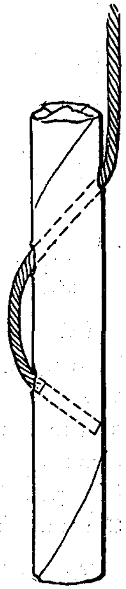


Fig. 6
Wrong

(d) Many blasters and miners do not realize that a detonator is so constructed that all the energy in it is compressed into about ½ inch of the closed end of the shell or that the detonator acts with greater force in one direction than in another, but think they should get into the cartridge as far as possible. Consequently, the business end of the detonator frequently bears against the paper wall of the cartridge and if the hole for the detonator is punched with a blunt tool the cartridge paper is often split so that the business end is actually exposed to view.

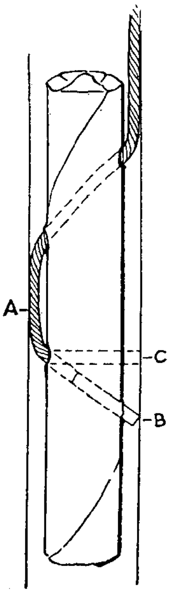


Fig. 7
Wrong

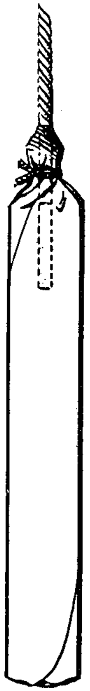


Fig. 8
Poor

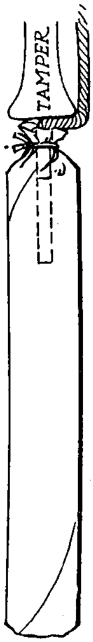


Fig. 9
Poor

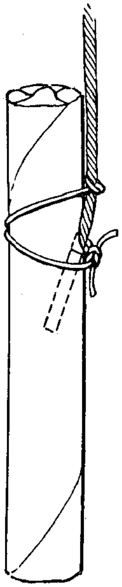


Fig. 10
Good

(e) When a cartridge primed in this manner is forced into a tight bore hole, as in Figure 7, pressure against the fuse at point A forces the business end of the detonator, B, to rub against the rough wall of the bore hole, and this may easily cause a premature explosion. Even if a premature explosion does not occur, the detonator is pushed into position C. There it shoots with greatest force into the wall of the bore hole and the result may be unexploded or burning powder.

Figure 8 shows a method quite commonly used in making primers for wet holes. The paper at the end of the cartridge is tied around the fuse and the joint is soaped or greased to keep out moisture. This method is good in that it places the detonator in the proper position, but great care must be taken in tamping to avoid making two sharp bends in the fuse, as illustrated in Figure 9. Such bends might crack the fuse coverings so that water could reach the powder train and cause a misfire.

Figure 10 shows the best method. It avoids sharp bends in the fuse and contact of fuse with naked powder. It leaves the end of the cartridge free for the tamping bar to rest against and the fuse is securely bound to the cartridge so that the detonator cannot be pulled out of place. In obtaining these advantages axial alignment is slightly sacrificed, but not to an extent that could be considered seriously detrimental.

PRIMING WITH ELECTRIC DETONATORS

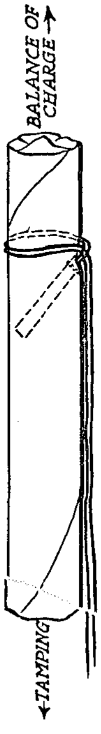


Fig. 11
Wrong

Figures 11 and 12 illustrate two common methods of priming with an electric detonator. In Figure 11 the detonator is very much out of alignment, pointing toward the wall of the bore hole instead of toward the body of the charge. In Figure 12 the detonator is in proper alignment, but should be pointed toward the bulk of the charge.

In certain kinds of mining where it is desired to have the holes fire in rotation it is sometimes desirable to have the cartridges primed as shown in Figure 12 with the primer placed at or near the bottom of the hole.

Figure 13 illustrates the method which most nearly approaches the ideal. The detonator is in proper alignment; there is no direct strain on the wires or the detonator; there are no kinks in the wires; and the blaster is almost sure to put the primer into the bore hole right end first. The only flaws in this method are that to some blasters it seems complicated and that with cartridges under 1⅛ inches in diameter there is a tendency to split the cartridge in punching the hole.

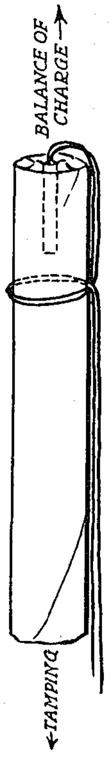


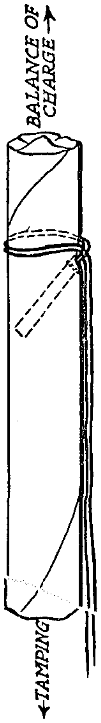
Fig. 12
Wrong

For small diameter cartridges and in cases where difficulty is experienced in getting the men who make primers to adopt the method shown in Figure 13, the method shown in Figure 14 will give about the same results without damage to the cartridge.

PRIMING WITH DELAY ELECTRIC DETONATORS

In priming with the new type of delay electric blasting cap, there is ordinarily no reason to deviate from the practices recommended cartridge free for the tamping bar to rest against and the fuse is securely bound to the cartridge so that the detonator cannot be pulled out of place. In obtaining these advantages axial alignment is slightly sacrificed, but not to an extent that could be considered seriously detrimental.

PRIMING WITH ELECTRIC DETONATORS



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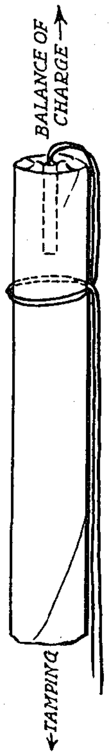

Fig. 12
Wrong

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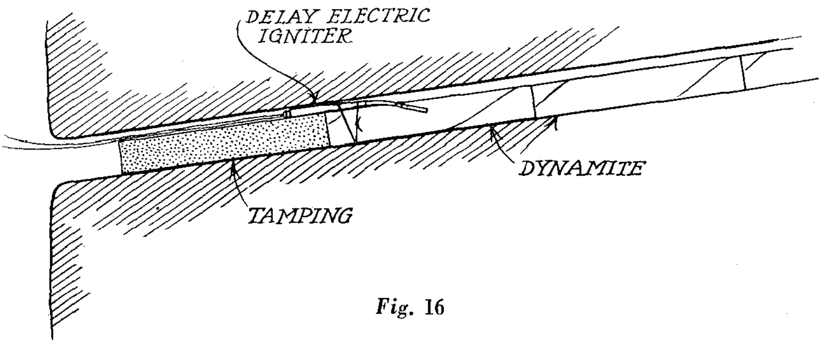


Fig. 16

PRIMING WITH PRIMACORD

LOADING WELL DRILL HOLES

Place an iron bar through the hole in the center of the spool of Primacord and lace a dynamite cartridge onto the end of the Primacord which is to be run to the bottom of the hole. Hold the spool over the drill hole, and, with the dynamite cartridge acting as a weight, allow the Primacord to run smoothly and slowly to the bottom. Draw the Primacord taut against one side, where it will not interfere with the loading or become entangled with the tamping bar or rope. When the sun is shining, a mirror can be used to very good advantage, as it enables one to place the Primacord on the side of the drill hole where it will be least subject to injury during the process of loading.

The detonating fuse now reaches from the top to the bottom of the hole, and the explosive charge can be broken any number of times if desired. The Primacord should be cut off the spool about two or three feet back from the top of the hole, and weighted down by a stone to keep the line taut. The end of the Primacord should be bent up and over the stone to keep it from slipping. The hole is then loaded in the usual manner.

After the hole has been filled with stemming material, remove the stone which has been holding down the end of the Primacord, raise the end of the Primacord off the ground and place an empty explosives box over it to protect it from injury until the remainder of the holes are loaded. If the weather is uncertain it is good practice to cover the Primacord under the box with waxed paper from the case of explosives, as this will keep it from getting wet in case of rain.

GENERAL PRECAUTIONS

All the methods of priming recommended are based upon two principles: first, placing the detonator so that its greatest force will be exerted upon the charge of explosive, not upon the stemming or the walls of the bore hole; and second, protecting the cap from accidental detonation and the fuse or the wires from injury. Painstaking application of these principles will aid in reducing premature shots, delayed shots and misfires and in securing maximum execution from the explosive.

If a round of several shots is to be fired with cap and fuse, as in many mines, it may be best to have the fuse cut and crimped on the caps, and the joint waterproofed, if necessary, by one man at a central station. If delivery of the primers to the working face can be satisfactorily safeguarded it may also be best to have the primers made at the central station where this operation can be more closely controlled and correct priming assured. In general, however, it is probably safer to have primers made at the face just as needed for loading the holes.

If the miner wears any other kind of lamp than the electric lamp, he should remove it while making primers and place it a safe distance away in the direction toward which the air current is moving. At no time during the handling of explosives should a lamp be worn or carried in such a way that sparks or flame from it will come in contact with the explosives or that the lamp may accidentally fall into them.

Primers made with cap and fuse should be handled very carefully to prevent sharp bends in the fuse or abrasion of any kind. If in loading a hole a portion of the fuse where the protective coverings had been ruptured should be in contact with the explosive charge, the emission of side sparks through the ruptured places might set fire to the explosive and possibly cause a premature shot. In a wet hole water would be likely to enter the powder train of the fuse through cracks in the covering and cause a misfire.

All primers should be handled with the realization that their potentialities for doing damage are much greater than those of either the detonator or the cartridge alone. The greatest care should be taken to keep the wires of electric primers from contact with all possible sources of current.

The best insurance against premature explosion of electric primers is the use of short circuited electric blasting caps. And be it remembered, that when short circuited caps are used, the short circuit should not be broken until the very moment of connecting the cap wires in the blasting circuit. This insurance, however, should not induce any relaxation in care in handling electric blasting caps.

LOADING BORE HOLES

The most important precautions to prevent accidents in loading bore holes are to protect the explosives from all impact, grinding friction and from sparks and flame. These are the most frequent causes of premature explosions.

Inasmuch as the bore holes used in the various kinds of blasting operations include holes of practically all diameters from one inch to twelve inches, also sprung holes and coyote tunnels, the application of these two general precautions involves considerable variety of procedure.

To begin with, all explosives should always be protected in every way possible from sparks from locomotives and steam shovels. Especially is this true of black powder and straight dynamite.

Second, granular explosives should be loaded in the cartridge shells or through funnels whenever possible. If the shell is opened and the loose explosive poured into the bore hole, some of it is likely to be spilled around the mouth of the hole, and then there is always the hazard that this will be exploded by being ground under foot or struck by a metal tool. Moreover, loose explosive is sure to be smeared on the sides of the bore holes and in tamping this may be exploded by being ground against the side of the hole or by being pinched between two pieces of loose rock. The explosion of even a small quantity of dynamite at the mouth of the hole or along the bore hole may initiate a premature explosion of the loaded charge that would be very disastrous.

In loading small diameter bore holes, the cartridges can usually be pushed to the bottom of the hole with the wooden tamping stick so that there is no need to open them. With well drill holes and large cartridges, if the holes are straight and smooth, the cartridges can usually be dropped free to the bottom of the hole. This is a common practice and, except with straight nitroglycerin dynamite, we know of no instance where dropping cartridges of standard explosives in normal condition has resulted in detonation from impact.

If well drill holes are ragged or partially caved it becomes necessary to lower the cartridges on a rope and pin, or even to load loose explosives. First clean the hole as much as possible by vigorous use of the tamping block. Then lower the cartridges carefully. If a cartridge becomes stuck and cannot be loosened by means of the rope, do not attempt to force it down with the usual heavy cylindrical tamping block. Take a tamping block of one of the types shown in Figure 17, punch a hole through the center of the cartridge with the spike or wedge, and churn this spike or wedge very carefully up and down a few times to enlarge the hole. Then the remainder of the cartridge can generally be dislodged by the shoulder of the block. When the block is taken out of the hole, rest the end in a clean, empty box or lay the block on a mat of gunnysacks to prevent grit or bits of rock from sticking to it. As an additional safeguard it is always advisable to pour water down the hole before starting to dislodge blocked dynamite and at intervals during the operation. Never put a metal pipe or a drill steel, or even a wooden tamping block tipped with metal, into a bore hole containing explosive.

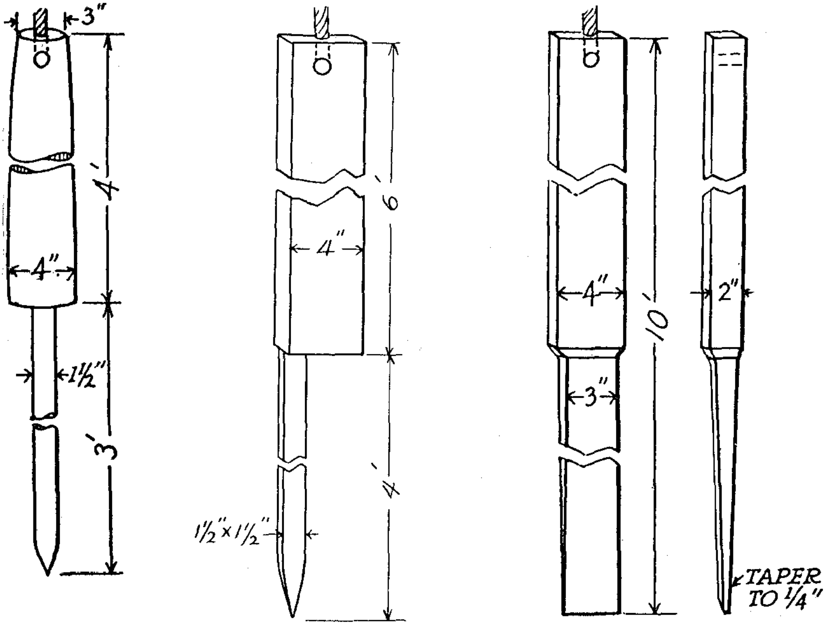


Fig. 17

If a well drill hole is so ragged that cartridges can not be lowered by means of a rope and pin, the explosive must be removed from the shells for loading. Gelatin dynamite is then the safest type. It can be cut into pieces and these can be dropped into the hole a few at a time. If a granular explosive must be used, it should always be of the ammonia type, never straight nitroglycerin dynamite. It should be poured in a thin stream down the center of the hole, watching continually to see that it is going to the bottom of the hole. If the explosive blocks the hole and builds up at some point above the level to which the quantity which has been loaded ought to come, beware of dropping a heavy tamping block on it. Take a light, thin pole or one of the tamping blocks illustrated and try to punch a hole through the center of the explosive and start it running downward.

Undoubtedly there are times when the hazard of dislodging a stuck cartridge or block loose dynamite is so great that it would be wiser to let it alone, and continue loading on top of it, if there is sufficient room, or put the primer in immediately. Decision upon this question must rest upon a careful consideration of all the circumstances in the case, especially the kind of explosive, the quantity already loaded, the condition of the hole, whether there is Primacord that would carry the detonation to the explosive in the bottom of the hole, or if not, an electric blasting cap in that portion of the charge, and whether the other holes can be depended upon to relieve the burden on the blocked hole.

The safest explosives for loading well drill holes are gelatin dynamite and low density ammonia explosives. The Institute of Makers of Explosives does not recommend straight nitroglycerin dynamite for well drill blasting under any circumstances because it is too sensitive for safety in this kind of work. There is real protection in selecting the right explosive and loading it in a manner that requires very little use of the tamping block. In fact, the best modern practice avoids the use of the tamping block in well drill holes for compacting either the explosive or the stemming. Except in very shallow holes, a plastic gelatin will spread from the fall in the hole sufficiently to largely exclude air spaces. If cartridges of ammonia dynamite are slit, they will bulge from their own weight and the impact of the successive cartridges and thus fill the hole. One of the advantages of the large cartridges of 16 or 24 inches length and 5 to 7 inches diameter for well drill holes is that their weight causes them to pack more solidly when dropped into the holes than do shorter cartridges. Another advantage of the long cartridge is that they are not so likely to become stuck in the hole as are shorter cartridges.

With smaller diameter bore holes it is often desirable to tamp the explosive solidly in the bottom of the hole, but this should never be done by violent use of the tamping stick. Moreover, the tamping stick should always be a wooden rod cut squarely across and having no metal parts. The principal source of danger in tamping holes is from grit. Consequently it is of great importance to clean a bore hole as thoroughly as possible before starting to load. Where compressed air is available blowing the holes out is the most effective method. No matter how well a hole may be scraped out or blown out, however, some grit always remains. If the tamping is done too violently, so that the rod penetrates the cartridges of explosives, there will also probably be some explosive smeared on the sides of the bore hole. The grinding of a heavy metal or metal-tipped rod against the grit may strike a spark which will explode the powder smeared on the sides of the hole and lead to the premature explosion of the charge. Some metals, such as lead, copper, brass, bronze and babbitt, are less likely to strike a spark than iron and steel, but the weight of any metal or metal-tipped rod makes it a dangerous implement for tamping explosives. Even with a wooden rod there is still some danger from grit grinding on grit and on the sides of the bore hole, so that the tamping stick should never be wielded with great force. A short, firm, but not violent, stroke is best.

It is always dangerous to force a cartridge into a bore hole, whatever the diameter of the hole. The best means to prevent cartridges from getting stuck in bore holes are to order cartridges of the proper size to slide easily into the hole, to keep the drill bits up to gauge, and to have the holes drilled as straight and even as the nature of the material will permit. The well drill operator should keep an accurate log of the hole—whether cavities are encountered, whether holes drift off materially in any direction. These are important things for the blaster to know and should be furnished to him. If a cartridge does become stuck, efforts to dislodge it should be made only with a wooden tamping stick or block, never a metal pipe or a drill steel or an auger, and the wooden implement should be used only to exert a firm pressure, never a quick, sharp blow.

When holes are sprung, it is of utmost importance to leave ample time between springing shots for the hole to cool, and also between the last springing shot and the loading of the main charge. Gelatin dynamite and electric detonators are the safest agents for springing holes. Gelatin dynamite is also the safest explosive for loading a sprung hole as it does not seep into cracks and crevices in the chamber and create the hazard, as a granular explosive does, that it may be pinched between loose rocks under the pressure of the tamping stick and explode prematurely. If blasting powder or a granular dynamite is used for loading a sprung hole, the precautions for tamping described above should be rigidly observed.

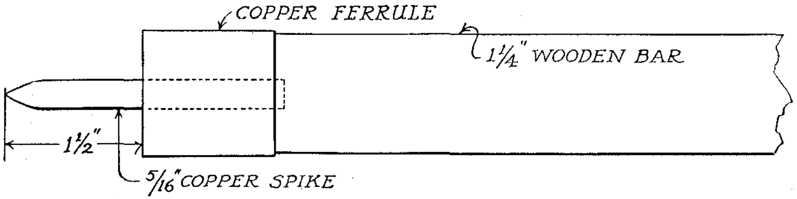
In open pit mines working the softer ores the most economical results are secured with a low strength ammonia explosive in sprung holes. Inasmuch as a granular dynamite must be loaded loose in such holes, it is important to select an explosive which is free running and relatively insensitive; to prevent the powder from being spilled around the bore hole where it may be exploded by being ground under foot or struck with a metal tool; and to use a light weight tamping stick.

In loading coyote holes care should be taken in proportion to the large quantity of explosives to be handled. Blasting powder is loaded in the kegs unopened and small diameter dynamite cartridges are loaded in the cases. Large diameter cartridges—5 x 16 inches is the customary size—are removed from the cases and stacked snugly on their sides. The usual procedure is to lay a line of plank in the center of the floor of the tunnel, station the loading crew along the plank at short intervals and let them shove kegs or cases along the plank from man to man. The plank should be smooth and free from nails and the possibility of violent friction and of sparks, as from workmen's shoes, should be reduced to the minimum. Where artificial light is needed, as for stacking the explosives in the crosscuts, making primers and connecting wires, an approved type of electric flashlight with no exposed live contacts should be used. No open light of any kind should be permitted within the tunnel. The electric flashlights themselves should be tested to make sure that there is no possibility that accidental contact between the metal parts of the flashlight and the wires of an electric blasting cap, or of a connected circuit, will cause a premature detonation. If necessary, wrap all exposed metal parts of the flashlight with friction tape.

A misfire in a tunnel blast creates such an awkward and dangerous situation that the firing system should be arranged and all wire connections made with the most exacting care.

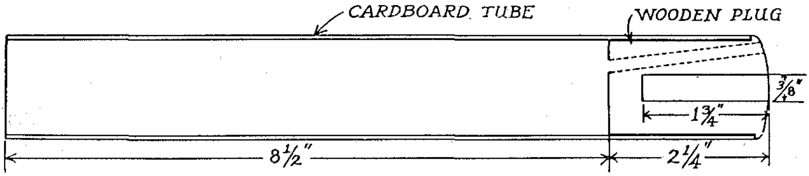
If a thunderstorm threatens while holes are being loaded in any outside blasting operation, stop the loading at once, for there is danger that lightning may strike the explosive direct, or if the loaded holes have been primed with electric detonators, still more danger that lightning may discharge electricity into the detonator wires. Send all but one or two men off the work, have them see that detonator wires in holes so primed are short circuited, turn empty dynamite boxes over loaded holes and return unloaded explosives and detonators to the magazines. The time to ward off accident from a thunderstorm is when the first threat of storm is observed. If work is continued until the storm actually breaks then the steps recommended to protect the explosives from lightning become fraught with danger for the men carrying them out.

The general rule in loading a charge is to place the primer last or next to last in the bore hole with the business end of the cap pointing toward the bulk of the charge. However, where the holes of a round



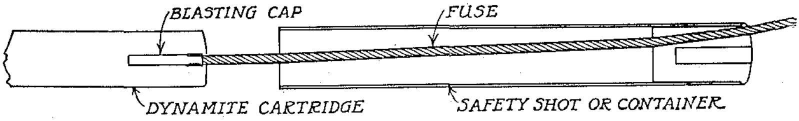
LOADING STICK USED IN LEAD-ZINC MINES

Fig. 18



SAFETY CONTAINER FOR PRIMER

Fig. 19



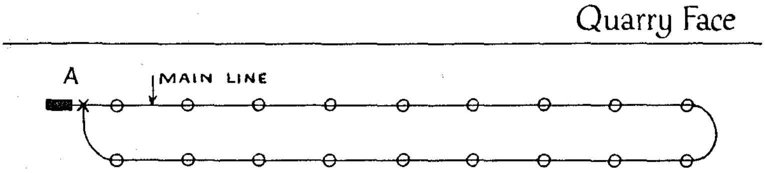
PRIMED CARTRIDGE READY TO BE PUSHED INTO PLACE IN SAFETY CONTAINER

Fig. 20

to be fired in rotation are close together, there is always the chance that the explosion of one bore hole will blow off the collar of an adjacent one, pulling the cap out of the primer or throwing the entire primer out of the hole, and thus leaving unexploded dynamite in the muck or in the bottom of a partly broken hole. To avoid this danger, the primer should be placed near the bottom of the hole. Then if the collar of the hole is blown off, the electric current will already have passed through the bridge of the delay electric blasting cap or igniter, or if cap and fuse are being used, the fuse will generally have burned far enough down in the bore hole to insure the firing of the charge.

When the primer is placed near the bottom of the hole the most favorable position for the cap is pointed back toward the bulk of the charge, and with delay electric blasting caps, there is no objection to this method of loading the primer. Neither should it give any trouble with a cap and fuse primer, if the fuse is of a good grade and the work is warm and dry, but it is not advisable where the fuse is cold or the hole wet. Under the latter conditions the only thing to do is to place the primer as high as possible without the risk of its being cut out of the round and take extra care to tamp solidly to the mouth of the hole.

When Primacord is used as a main line it is well to make a complete circuit of the main line, so that every row of holes will have two paths by which the detonating wave can reach it.



A hazard that not infrequently arises in loading holes in lead-zinc mines is due to the fact that because of the water course and pocket formation of the ore bearing rock, a boulder may drop and close the hole. Suppose there are from 5 to 10 cartridges of explosive in the bottom of a bore hole and a rock drops, cutting off from 3 to 5 feet of the hole. It would be extremely dangerous to attempt to dislodge this rock with a blow gun, a drill steel or steel spoon, because any of these might cause friction or strike sparks from the rock which might set off the explosive in the bottom of the hole and probably strewn along the hole. If the boulder can not be pushed aside with a wooden tamping bar—and this should be without the copper ferrule and spike with which tamping bars in these mines are usually equipped —so as to permit the bar to pass through to the bottom of the hole, the safest measure is to place a primer against the boulder and shoot it. There is so much hazard in loading primers in the irregular holes of the lead-zinc mines that a special container is recommended.

This device, as shown in Figure 19, consists of a tough cardboard tube, of such an inside diameter as easily to accommodate the size cartridge in use, with a wooden plug 2½ inches long fastened in one end. Through this plug runs a diagonal hole just large enough to permit safety fuse to slide through it easily, and in the center of the plug is a dead end hole 1¾ inches deep and ⅜ inch in diameter to accommodate the standard length spike on the tamping bar, which is 1½ inches long and $\frac{5}{16}$ of an inch in diameter. A foot or so of the fuse is first drawn through the diagonal hole in the plug. A blasting cap is next crimped on the fuse and inserted in the dynamite cartridges as seen in Figure 20. The primed cartridge is then pushed back into the cardboard tube. As the hole for the fuse is a neat fit, the fuse itself will slide through the plug but the crimping on the blasting cap prevents it from being pulled through this hole. Finally the end of the tube is crimped over the end of the cartridge and the encased primer is placed on the spike of the tamping bar and pushed back in the usual manner.

It is a good plan to have some one workman make up the primers at some point remote from the working faces. This would insure uniform location of the blasting cap in the cartridge and eliminate the dangerous practice of taking the exposed caps to the working faces along with the dynamite and subjecting them to the possibility of being stepped upon or being hit by falling pieces of rock. The use of this container and the precaution of making up primers at a distance from the working faces should go a long way to decrease the hazards of blasting in lead-zinc mines.

The most important precautions that should be observed in loading permissible explosives in coal mines are designed to prevent accidents from misfires, burning charges and blown-out shots rather than accidents in the process of loading. The chief of these precautions are to clean all dust out of the bore hole, to place all the cartridges for a charge in the mouth of the bore hole one after another with the part cartridge, if there is one, at the back end of the column with its cut end toward the back of the hole, and push them back all together, and to tamp holes with clay, sand or other non-combustible stemming, a mixture of 2/3 sand and 1/3 clay slightly moistened is best, which has sufficient weight and cohesiveness to pack solidly enough to prevent the shot from blowing out.

Tamping holes properly also precludes the dangerous practice of short fusing, which is still followed despite the fact that it is contrary to law in many states, and which is responsible for many accidents.

Of course, permissibles are the safest of all explosives for coal mining and the only type that should ever be used in gaseous or dusty mines. In non-gaseous mines, pellet powder, in turn, is safer than granular blasting powder. The chief safety feature of pellet powder lies in its compressed form and paper wrapper; therefore, the pellets should never be crushed in the bore hole nor should the wrapper be taken off. The chief danger of granular blasting powder is its great inflammability; therefore, it should be vigilantly protected from sparks and flame. When pouring powder from keg to jack and when making up cartridges, the miner should always remove his cap lamp, unless it is an electric lamp, and place it a safe distance away in the direction opposite to that from which the air current is coming. He should try to avoid spilling powder and should always close the keg or jack immediately after pouring powder out or in. Blasting powder kegs should never be opened with a pick. Blasting powder kegs should not be opened in any manner except by removing the bung in the top of the keg provided by the manufacturers.

TAMPING BORE HOLES

Confining the explosive solidly in the bore hole with stemming is necessary to guard against accidents as well as to secure the best execution from the explosive. Imperfect confinement of the charge may result in incomplete detonation or burning explosive, both of which produce gases which are dangerous underground, or in a blown out or windy shot, which is an extremely dangerous occurrence in a gaseous or dusty coal mine because it is likely to start a gas or dust explosion.

If a charge primed with cap and fuse is unstemmed there is often the chance that the fuse may curl in such a way as to spit sparks from the lighted end into a bore hole which may ignite the explosive and cause a premature blast. An unstemmed hole may also be fired prematurely by sparks from the fuse lighter.

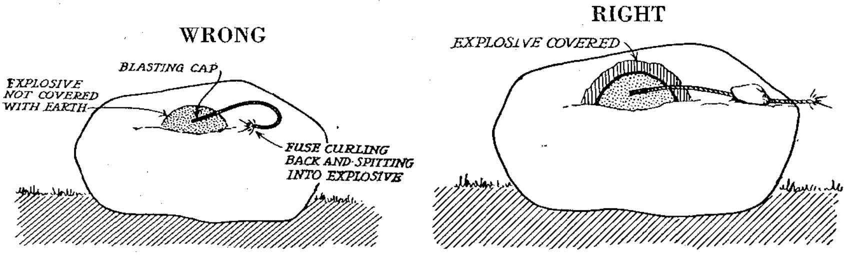

WRONG
BLASTING CAP
EXPLOSIVE NOT COVERED WITH EARTH
FUSE CURLING BACK AND SPITTING INTO EXPLOSIVE
RIGHT
EXPLOSIVE COVERED

Fig. 21

Again, in some classes of work, a considerable length of fuse extends out of the bore hole and miners often fold up this extra length of fuse and push it into the mouth of the hole so that the end will protrude in a convenient position for lighting. Such treatment of fuse may easily rupture the coverings of the powder train and the resulting emission of sparks at ruptured places may cause the premature explosion of an unstemmed charge.

A good practice in firing rotation shots with cap and fuse is to have the uncapped ends of all the fuses dipped in contrasting color paint —black on white fuse, etc. The shot-firers then trim only the painted end fuse, eliminating the chance of trimming a fuse twice.

In coal mines failure to tamp holes is often due to the practice of short fusing (a length of fuse too short to extend from the charge to the collar of the bore hole or too short to allow the blaster to get to a safe place after lighting the fuse), which still persists in spite of the fact that it is extremely dangerous, and, in many states, contrary to the law. As the primer with short fuse must be pushed back into the bore hole after the fuse is lighted, there is an excellent chance for the end spit to ignite particles of explosive scattered along the bore hole or even the main charge. The use of adequate stemming should therefore be insisted upon as a means of stopping short fusing.

Of course the hazard that premature shots will be caused by sparks coming in contact with the explosive charge is much greater with pellet powder and with highly inflammable high explosives than with the relatively uninflammable ones.

With small diameter bore holes it is usually necessary to pack the stemming material solidly in the hole by use of the tamping stick, but with well drill holes that is unnecessary. The stemming is usually fines or sand and pouring either into the hole compacts it sufficiently and eliminates one of the possible sources of premature explosion or misfires.

The relation of tamping sticks and the methods of wielding them to accident prevention has already been discussed on pages 29-30.

There is also a direct connection between the choice of stemming material and accident prevention. The safest material for stemming is clay or sand free from sharp particles. Sharp particles in the stemming are likely to abrade the fuse or the detonator or squib wires and lead to misfires, and any material which is too light and fluffy to pack solidly in the bore holes may lead to blown-out shots or incomplete detonation. Rock dust is not heavy enough nor cohesive enough to hold the gases. Paper, sawdust, bark, bug dust, in fact any inflammable material is dangerous for stemming because likely to catch fire and add to the poisonous gases evolved in detonation.

FIRING SHOTS

The chief precautions to prevent accidents when firing with cap and fuse are to use a sufficient length of fuse to allow the blaster to reach a place of safety, to make sure that the fuse is lighted, and to refrain from returning to a shot that has failed to fire until ample time has elapsed to give assurance that it is a misfire and not a delayed shot. The rigid observance of these precautions would do away with many accidents.

The improvements made in recent years in delay electric firing devices have increased their use underground, both because they reduce the number of misfires and because they permit firing all blasts from a point at a safe distance from the face. This latter is of particular importance in shaft sinking where with cap and fuse shooting the blasters' lives depend on the hoisting apparatus not failing after the fuses are lighted.

The chief precautions against accidents when firing with electricity in underground work are keeping electric detonators short-circuited until the moment of connecting them in the blasting circuit and keeping leading wires short-circuited until the moment of connecting them to the source of current.

The use of the power wires of the mine for blasting in gaseous and dusty coal mines while the men are in the mine is not recommended. Blasting with 250 to 500 or more volts is hazardous in the extreme, not so much because of the effect on the explosive, but because of the possibility of igniting gas or dust by electric arcs while the current remains in the wires after the actual blasting has been done and the wires badly entangled at or near the recently blasted face with its released gas or dust or both. Duplex leading wire should not be used except for single shot firing. Two single leading wires, which are kept in good condition, make good insurance against misfires. Leading wire should be at least No. 18 gauge, preferably 14 gauge for anything except single shots, and should not be lengthened by splicing with detonator leg wires. Blasting machines should not be overloaded, and it must be remembered that their capacity is not as great under wet conditions as in dry.

An additional suggestion for electric firing in mines, where blasting machines are used, is that the firing cable be hung on the timbers by means of insulators or staples. This will keep the wires off the ground and the rails and afford a protection against stray electricity and leakage of current. Of course, in underground work where there is a permanent firing line this should be installed on insulators.

In open work there is not so much chance that the wires of the blasting circuit will come in contact with bare live wires, charged machinery or stray electricity; yet, with the growing use of electric well drills and shovels, these hazards are on the increase, so that many of the precautions recommended for safeguarding electric firing in underground work apply also to outside operations, especially those as to keeping detonator wires and leading wires short-circuited until they are connected in the circuit or to the source of firing current.

Underground blasting with electric firing should be suspended during severe electrical storms on the surface.

In all electrical firing, above or below ground, it is of first importance for safety that the mechanism for furnishing current to the blasting circuit should be of an approved type and capable of delivering sufficient current to fire the circuit in question. In coal mines this should be either a standard blasting machine or other device approved by the Bureau of Mines. The use of dry cell batteries with exposed or inadequately protected terminals has been responsible for a large number of accidents. If a blasting machine larger than pocket size is used, it should always be tested with a rheostat before the blast to make sure that it is up to capacity. If a portable generator of the type designed especially for providing lighting or power current for farms, camps or country estates is used—as has been found practical on some remote blasting projects where it was desired to fire a larger number of holes at a time than feasible with a blasting machine, and where there were no power lines to be tapped—it should be capable of producing the required amperage and voltage, should preferably be a compound wound generator, and should be so equipped that the current can be instantly transferred from a phantom load to the firing circuit while the generator is running at full speed. If a power current is used for firing, there should be a switch in a locked box with key in the possession of the blaster.

When firing with a blasting machine near high tension power lines, it is important to avoid stringing the leading wires under the power lines or parallel to them, first, because of the possibility of an induced current in the leading wires, and second, because of the possibility that the leading wires may be flung by the blast into contact with power lines. Several blasters have recently suffered shock, burns and other injuries from ignorance or disregard of this latter hazard. If leading wires must be strung in such a position that the blast may throw them against power lines, it is advisable to weight them down.

In every kind of blasting it is imperative that warning should be given and that all persons should retire to places of safety before the blast is fired. In open pit mining and quarrying where springing shots and secondary blasting are frequent, portable iron shelter houses will afford safe refuge for the men relatively near the blasts and thus save much time.

All persons should retire to a safe distance, guards or red flags should be placed on any nearby roads to stop traffic from both directions, and warning should be given just before the blast is fired. Unsuspected caves, mud seams or other irregularities in a rock formation occasionally cause a blast to hurl pieces of rock much farther than could be anticipated, and this possibility should always be taken into consideration in determining the radius to be cleared before firing.

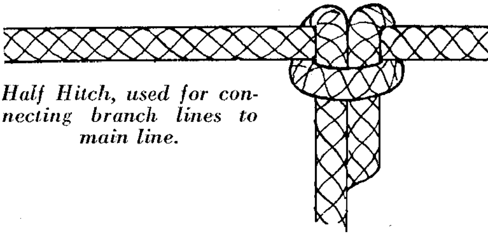
In mines where shooting is allowed on shift, it frequently happens that men are injured or killed because they walk unwarned through a crosscut into a room just in time to be caught by an exploding shot or because a shot blows through into their working place from an adjoining place. To prevent such accidents a warning should be sounded before each shot is fired, all entrances to places where shots are about to be fired should be guarded, and when two working places are being driven toward each other, the official in charge of that section should keep the men informed as to the relative position of the two places and the advance being made.

Leading wires should always be long enough to permit the man firing the shot to stand in a place of safety. Coal miners especially tend to use short cables. They keep cutting off the portion of the cable next the face that is damaged by the fall of coal and continue to use the cable after it has become much too short to allow them to retire to a safe distance from the face. Mine officials should be on the watch to prevent the use of short firing cables. A length of at least 100 feet is recommended.

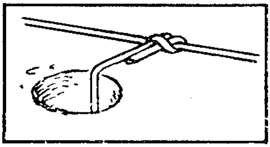
PRIMACORD BICKFORD

Precautions

Always make a tight connection between branch line and main line. When connecting holes to the main line, the Primacord leading from the mouth of each hole should be tied at right angles to the main line with a half hitch as shown.

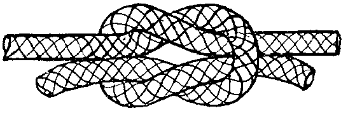


Half Hitch, used for connecting branch lines to main line.



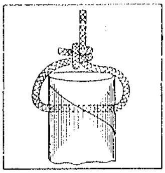
Primacord connections to main line.

If necessary to connect two or more lengths of Primacord in the main line, join the ends by tying them together with a square knot pulled tight. Do not use knot connections or splices in a hole.



Square Knot, to be used only on the main line.

In rainy weather, keep connections dry and protected.

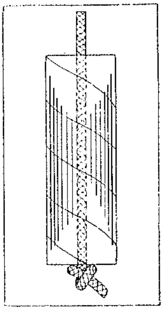


Thread the Primacord through a hole about three inches from top of cartridge and tie as shown.

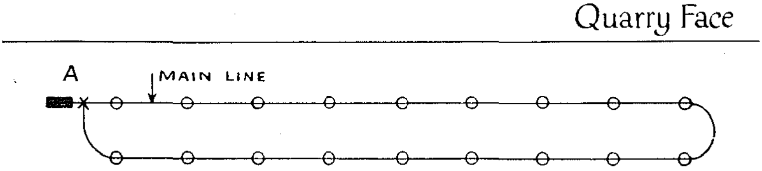
Always use unions to attach caps to Primacord.

Be sure the end of Primacord is freshly and squarely cut off and free of dirt before attaching the blasting cap.

The blasting cap should be placed on the main line nearest the quarry face. Other lines of holes should be connected to the main line in the order they recede from the face. Whenever possible it is well to make a complete circuit of the main line, so that every row of holes will have two ways by which the detonating wave can reach it.



Pass the Primacord through center of cartridge and tie a knot in the end of the fuse.



DOUBLE ROW OF HOLES

The end of the Primacord from the back line is wrapped around the main line at point X, making a regular connection. The Primacord should be detonated by means of fuse and cap or an electric cap properly attached at point A.

Make it a point to inspect and count all connections just before firing the blast.

RETURNING TO THE FACE

Although pellet powder gives off much less smoke than blasting powder, and although the poisonous fumes from permissible explosives and the types of dynamite recommended for underground work have been materially reduced in recent years, it is still unsafe to return to the face immediately after any blast underground, whatever the explosive. There is danger of igniting the powder smoke with open lights; there is danger of being so blinded by smoke as not to see loose roof, and there is danger of being overcome by fumes. No time limit can be set for returning upon a shot because the proper interval depends upon the type of explosive, size of charge, and the ventilation, but the regulations of each mine or tunnel should specify the minimum interval for safety and men should be trained to exercise good judgment in the matter. An hour, at least, is suggested unless the ventilation is unusually good.

SECONDARY BLASTING

Secondary blasting is responsible for many accidents that could easily be prevented. Where a number of shots is to be fired, block holing is safer than mudcapping because the explosion of one mudcap charge may dislodge the charge on an adjacent rock and scatter unexploded dynamite among the broken rock. Mudcapping should never be done in bituminous coal mines. Gelatin dynamite is safer for block holing than a granular explosive, especially where less than a whole cartridge is used per hole, because it removes the hazard that loose powder will be scattered about and exploded by friction or a spark. In mudcapping the charge should always be completely covered with mud not only because the confinement improves the execution of the explosive, but also because the mud covering removes the hazard that a curling fuse may spit into the explosive and cause a premature explosion.

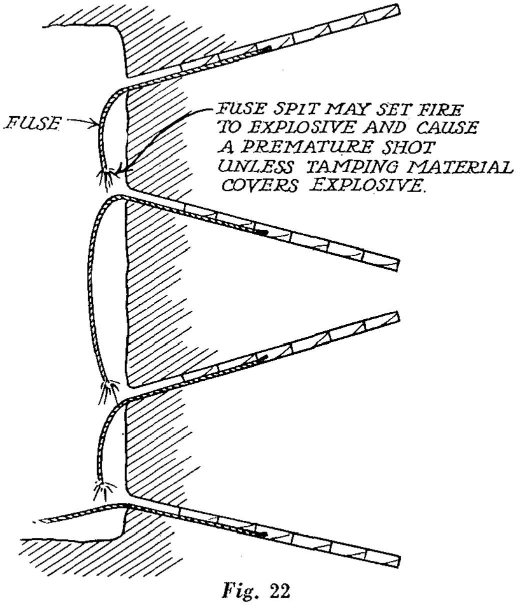


Fig. 22

One of the dangers of secondary blasting is that the men lighting fuses will be injured by missiles thrown by the shots that fire first. When a considerable number of shots is to be fired at one time, cut a signal fuse enough shorter than the shortest block hole fuse to give an interval between the burning time of the two which will permit the men lighting fuses to reach a place of safety, crimp a cap to this, place it where the flying particles of copper can not do any injury, and light this fuse just before the men start lighting the block hole fuses. As soon as the men hear the cap on the signal fuse explode, they should stop lighting and run to shelter.

BLASTING FALLS OF ROCK

Closely allied to secondary blasting is the blasting of falls of rock in coal mines. This should never be done by mudcapping in a gaseous or dusty mine because even a permissible explosive, when fired unconfined, may produce enough flame to ignite gas or dust. As most coal mines are dusty at times, if not continuously, the only safe procedure is to blast a rock fall by the block hole method.

PREVENTION OF MISFIRES

Misfires are dangerous because they leave unfired dynamite in places where it is likely to be subsequently exploded accidentally and to cause injury or death. Reducing the number of misfires therefore is a fundamental step for reducing the number of accidents and the way to reduce misfires is through selecting the safest explosive adapted to the work, providing proper storage, and following correct methods of priming, loading and tamping charges and of connecting and firing electric blasting circuits. A tabulation of the principal causes of misfires and the means of eliminating these causes follows.

FAILURES WITH MINERS' SQUIBS

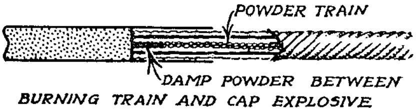
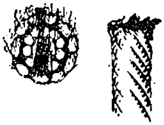
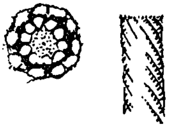
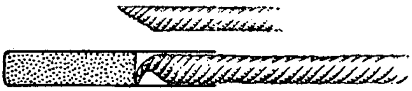
CAUSES	MEANS OF PREVENTION
1. The squib may have been damp.	1. *Keep squibs dry. Do not leave them lying around the mine loose or in an uncovered box.*
2. A little water in the hole through the tamping may have extinguished the squib before it reached the primer.	2. *In damp holes use a blasting barrel and shoot a squib through it to clear and dry it before putting it into the hole, or, better still, use electric squibs or fuse.*

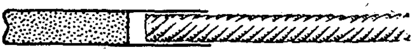
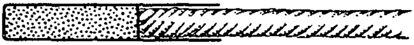
CAUSES	MEANS OF PREVENTION
3. A small piece of stemming may have dropped into the hole for the squib and clogged it.	3. *Use damp clay stemming and pack it tight. Be sure the miner's needle is smooth and straight and remove it very carefully.*
4. With stemming material wrapped in paper, the paper may have buckled in tamping and been dragged into the hole by the removal of the needle.	4. *Do not use paper covered dummies for tamping around a miner's needle. Use loose clay.*
5. The squib may have been thrust too far into the hole.	5. *Leave a little of the body of the squib containing the powder extending from the hole.*
6. With pellet powder, the miner's needle may have been thrust between the side of the pellets and the paper shell or between the shell and the wall of the bore hole instead of into the central perforation of the pellets.	6. *Be sure the point of the needle is in the central perforation of the last pellet. Do not crush any of the pellets.*

FAILURES WITH SAFETY FUSE OR WITH BLASTING CAP AND FUSE

CAUSES	MEANS OF PREVENTION
1. Wrong grade of fuse may have been used.	1. *Use waterproof fuse in wet work and suitable fuse in other work.*
2. Fuse may have become damp in improper storage.	2. *Store fuse in a cool, dry, well-ventilated place.*
3. Fuse may have been kept so warm as to cause the waterproofing material to melt and strike into the powder train, or to cause the fuse to dry out and crack so that water penetrated to the powder.	3. *Store fuse in a cool place. Do not leave it near stoves, radiators or steam pipes.*

CAUSES	MEANS OF PREVENTION
4. Fuse may have been cracked by uncoiling it while cold and water may have penetrated to the powder.	4. *Warm cold fuse at a temperature of from 70° to 80° F. for eight hours before uncoiling it.*
5. Fuse may have come in contact with oil, such as gasoline or kerosene, or grease may have been used for waterproofing from which oil penetrated to the powder.	5. *Keep fuse away from any light or heavy oils in transportation and storage. Do not use grease for waterproofing. Most greases contain light oils. Do not use paint as a waterproofing material if it contains a light oil drier. Use a cap sealing compound, miner's soap or wax.*
6. In a wet hole water may have been forced through the waterproofing of the fuse into the powder train by excessive pressure in tamping.	6. *In holes full of water, especially in shafts, use waterproof fuse with cap sealing compound and tamp carefully to prevent the development of too much pressure.*
7. Fuse may have been injured by coarse, sharp stemming material or by a metal tamping bar or by rough or careless tamping.	7. *Use fine stemming material, preferably sand or clay, free from all sharp particles. Use wooden tamping bars and tamp carefully, but firmly.*
8. Protective coverings of fuse may have been broken by making sharp bends or kinks in the fuse, thus allowing moisture to damage the powder core.	8. *Do not make sharp bends or kinks in fuse, especially in cold weather.*
9. Use of short fuse and consequent hasty loading and tamping may have resulted in rupturing the fuse covering and allowing moisture to enter the powder train.	9. *Cut fuse long enough to extend out of bore hole and load and tamp carefully.*
10. With pellet powder, the fuse may have been pulled out of the primer cartridge in loading and tamping.	10. *Run the fuse all the way through the primer cartridge, double the end back into the hole and pull the fuse tight. Do not tie a knot in the end of the fuse.*

CAUSES	MEANS OF PREVENTION
11. With pellet powder, the fuse may not have been gashed or cut properly at the end.	11. *Gash the portion of the fuse that will lie inside the primer cartridge three or four times, cut the end on a long slant and turn this end back into the central hole of the cartridge in such a way as to open the gashes and bring the powder train in the slanting end against the wall of the pellet, not against the fuse.*
12. End of fuse may have absorbed moisture from the atmosphere so that it did not burn through to the explosive in the cap.  POWDER TRAIN DAMP POWDER BETWEEN BURNING TRAIN AND CAP EXPLOSIVE *Fig.* 23	12. *Unless fuse is freshly cut from the roll for each cap, cut one-half inch off the end just before inserting it in the cap.*
13. In cutting the fuse, its waterproofing material may have been smeared over the end of the powder train so that this melted on the explosive in the cap and prevented it from igniting.  *Fig.* 24	13. *Be sure that the knife blade, or the cutting device of the cap crimper used for cutting fuse, is clean and sharp. Do not cut fuse with an axe, spike, file, pliers or any dull or blunt edge.*  *Fig.* 25
14. Fuse may have been cut at such a slant that on being inserted into the cap, the end became doubled back and prevented the spit of the fuse from striking the explosive in the cap.  *Fig.* 26	14. *Cut fuse straight across with a clean sharp knife or fuse cutter.*

CAUSES	MEANS OF PREVENTION
15. Fuse may not have been pushed all the way down to the explosive in the cap.  *Fig.* 27	15. *Always be sure that the end of the fuse is seated squarely on the explosive in the cap. If the end of the fuse is too large to enter the cap easily, cut off a small piece with special care not to spread the fuse and try again. If this fails, hold the end of the fuse straight upward and roll it slightly with the finger and thumb or reshape it with the crimping jaws of a sleeve-type cap crimper, taking care that the powder does not fall out of the fuse.*  *Fig.* 28
16. The powder may have dropped out of the end of the fuse and the spit have been smothered by the wrapping before it reached the explosive in the cap.	16. *Never whip the ends of fuse or handle them in any way so that the powder may fall out.*
17. Fuse may have been pulled out of the cap in loading the primer and tamping.	17. *Never attempt to crimp the cap on the fuse with the teeth or a knife. Use only a cap crimper of approved type and make a tight crimp.*
18. Fuse may not have been lighted.	18. *Be sure that each fuse is really burning before lighting the next. Use lead spitter, hot wire lighter or other sure means of ignition in wet work.*
19. Blasting cap may have become wet or damp in storage. It is possible for humidity alone without actual precipitation to make the explosive in a cap too damp to explode.	19. *Store blasting caps in a dry, well-ventilated place.*

CAUSES	MEANS OF PREVENTION
20. Water may have dropped into the cap, or humid mine air may have condensed in it.	20. *Always replace the felt pad and lid on the cap box immediately after removing a cap and keep the box in a place protected from rain or dripping water. Do not leave caps in the mine over night.*
21. Moisture may have been introduced into the cap by blowing in it to remove foreign material.	21. *Never blow into a cap.*
22. Some foreign material such as sawdust may have gotten into the cap and formed an obstruction between the spit of the fuse and the explosive.	22. *If foreign material is suspected in a cap, tap the open end lightly on dry wood, or on the thumb-nail of the other hand.*
23. Oil may have gotten into the cap. Even highly inflammable oil will reduce the strength of a cap and may drown the spit of the fuse.	23. *Do not use any grease or paint containing light oil to waterproof the joint between cap and fuse for the light oil will work its way down through the slightest crack into the cap. Use waterproofing compounds manufactured for this purpose.*
24. Water from a wet bore hole may have penetrated into the cap.	24. *Crimp the cap on the fuse tightly and dip the joint in cap sealing compound a few hours before making the primer. If a smooth covered fuse is in use, a water-tight joint can usually be made with a cap crimper which leaves no vent and no waterproofing will be needed.*
25. The cap may have been pulled out of primer in loading and tamping.	25. *Tie the fuse securely to the primer cartridge and load carefully.*
26. Fuse may have been laced through the primer cartridge.	26. *Never lace fuse through dynamite. Make primers by approved methods.*

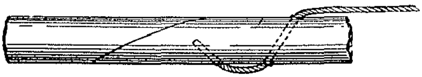


Fig. 29

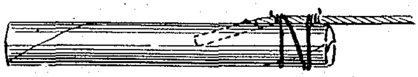


Fig. 30

CAUSES	MEANS OF PREVENTION
27. Primer cartridge may have been cut off by adjacent shots.	27. *Place primer near the bottom of the hole. If the fuse has burned beyond the point where the collar is blown off, it will probably keep on burning and fire the cap.*
28. Holes may have been cut out of round by cutting fuses too short to give proper rotation or by lighting them in wrong order.	28. *Be sure to cut fuses long enough to give proper rotation and to light them in right order.*

FAILURES WITH ELECTRIC BLASTING CAPS AND DELAY ELECTRIC BLASTING CAPS

CAUSES	MEANS OF PREVENTION
1. Electric detonators may have been damaged in improper storage. Dampness is likely to affect the cap or corrode the wires so that they break easily.	1. *Store electric detonators in a dry, well-ventilated place.*
2. The bridge wire of the cap may have been broken by jerking the wires or other rough handling.	2. *Handle electric firing devices carefully. Test each cap with a circuit tester before making the primer and before connecting the wires in the blasting circuit.*
3. The cap may have been pulled out of the primer in loading and tamping.	3. *See that the cap is securely tied or otherwise fastened in the cartridge and load carefully.*
4. There may have been a break in the blasting circuit.	4. *Test the blasting circuit with a circuit tester before attempting to fire.*
5. In scraping insulation from No. 18 or finer wire with a knife, the wire may have been so nearly cut in two that it separated after connections were made, causing a break in the circuit difficult to find.	5. *Uncoil the layers of insulation from this fine wire instead of scraping them off with a knife.*
6. Poor connections may have created such high resistance in the circuit that the current was not strong enough to fire all the detonators.	6. *Scrape or sandpaper the wire ends until they are clean and bright and twist them together tightly. Do not make loop connections.*

CAUSES	MEANS OF PREVENTION
7. A wire of a waterproof electric blasting cap may have been cut and the connection made without scraping off the enamel under the cotton insulation.	7. *Do not cut wires of waterproof electric blasting caps. Make connections on the tinned ends. If absolutely necessary to shorten wires, make sure the enamel is thoroughly scraped off.*
8. A piece of wire cut from a waterproof electric blasting cap may have been used for connecting wire without scraping off the enamel.	8. *Do not use leg wires of caps for connecting wires. Use only regular connecting wire.*
9. The blasting machine may not have delivered a current of sufficient amperage and voltage to fire all the caps.	9. *Make sure that the blasting machine is of sufficient capacity and in good condition. Test it with a rheostat.*
10. The blasting machine may have been wet so that a short circuit was set up in its mechanism.	10. *Keep blasting machines dry. Do not leave them underground over night.*
11. The blasting machine may not have been operated hard enough to develop its full capacity.	11. *Always operate a blasting machine with all possible force. Operate the machine two or three times to magnetize the field magnets before connecting the leading wires.*
12. Parallel or multiple connections may have been made for firing with a blasting machine. Blasting machines are not designed to develop sufficient current for ordinary parallel or multiple connections.	12. *Always connect all the caps in one series for firing with a blasting machine or, if circumstances require it, in a graded parallel series.*
13. The power circuit may not have delivered a current of sufficient amperage and voltage to fire all the caps. A generator of sufficient capacity may be running at full speed, but unless it is actually delivering the power at the moment of firing, the interval of time necessary to build up the current is likely to cause trouble.	13. *Be sure that the power line is actually delivering adequate current at the time and place the blast is made. Do not attempt to fire a series circuit with an alternating current of less than* 40 *cycles.*

CAUSES	MEANS OF PREVENTION
14. Leading wires of too small gauge and consequent high resistance may have been used, thus reducing the current delivered to the caps.	14. *Use nothing smaller than No.* 14 *leading wire for a circuit containing more than three caps.*
15. The wires may have been half-hitched around the cartridge and the insulation may have worn through, causing a short circuit.	15. *Make primers so that wires do not cross each other.*
16. The insulation of the wires may have been rubbed off by too forceful tamping with a metal bar, causing a short circuit, or a wire may have been broken in this way.	16. *Use wooden tamping bars and tamp carefully.*
17. Worn insulation on leading wires or an untaped splice or wet leading wires may have caused a short circuit in these wires and leakage from the blasting circuit. Short circuits are especially likely to occur in duplex leading wire under these conditions.	17. *Do not use duplex leading wire where more than one cap is to be fired in one shot. Use well-insulated single wire, rubber covered for wet work. See that leading wire is dry and in good condition. Test it for short circuits with a circuit tester.*
18. Leading wires or connecting wires may have come in contact with rails, pipes or machinery and caused a ground or short circuit.	18. *Keep all wires of a blasting circuit out of contact with any metal object.*
19. Joints in the wires may have lain in water or on wet ground and caused a short circuit.	19. *Tape wire joints carefully or keep them away from contact with water or wet ground.*
20. In wet work, or only slightly damp work where the rock or earth contains mineral salts, there may have been enough leakage of current from the circuit to cause the caps in the middle of a series to misfire.	20. *Use electric blasting caps with enamelled wire or parallel connections; in sea water or other hard water use both.*
21. Too many electric blasting caps may have been connected in one series, resulting in current leakage from center caps.	21. *Never connect more than* 50 *ordinary electric blasting caps in one series even in dry work; in wet or damp work, and if the water is hard, use blasting caps with enamelled wires.*

CAUSES	MEANS OF PREVENTION
22. The wrong wires may have been connected with each other.	22. *Be sure that all wires are connected so as to give a continuous path for the current without cutting any of the caps out of the circuit.*
23. Two different makes of detonators may have been used in the same series or multiple series. Electric blasting caps of different manufacturers have different firing characteristics.	23. *Be sure that all detonators in any blast are of the same make.*
24. The collar of the hole and the primer may have been cut out of the round by the explosion of an adjacent hole.	24. *When firing rotation shots place the primer near the bottom of the hole.*
25. Holes may have been cut out of a round by placing the wrong delay in the wrong hole.	25. *Observe the tag numbers carefully and place the right number in the right hole.*

FAILURES WITH DELAY ELECTRIC IGNITERS

CAUSES	MEANS OF PREVENTION
1. The causes listed for failures with electric detonators apply also to delay electric igniters.	1. *Follow the same precautions.*
2. Many of the causes for failures with fuse and blasting caps apply also to delay electric igniters.	2. *Use the same precautions in handling this fuse as with ordinary fuse and especially in attaching a cap to it. Be sure to cut off at least one-half inch of the igniter fuse before attaching a cap.*
3. The rubber sheath of the igniter may have become so dry as to break, allowing moisture to enter the gas vent in the igniter shell and spoil the ignition compound.	3. *Use fresh igniters. Be sure they are not old or dried out.*
4. In a wet hole, water may have penetrated the joint between cap and igniter fuse.	4. *Use a cap crimper which leaves no vent. After the cap is crimped tight to the fuse, dip the entire igniter in cap-sealing compound.*

if the load is broken, firing a fresh primer in the top charge would probably explode only this charge, leaving matters in worse condition than before. Therefore, in case of misfire of a deck-loaded well drill hole, it will probably be necessary to remove both tamping and explosive down to the bottom charge if electric blasting caps are used. If Primacord is used a primer on first deck charge will probably detonate all lower charges.

If the misfire falls in the second class referred to, namely, where the exploding holes have broken away the burden from the hole or holes that failed, it is likewise often necessary to remove part or all of the explosive. This is a dangerous operation at the best, and should be undertaken only by a competent and experienced man.

A tool which has been used successfully for removing explosive from a well drill hole can be made as follows: Take a copper or brass tube four or five inches in diameter and about twenty inches long, have the edges of one end of the tube sharpened and have two holes drilled on opposite sides about half an inch up from this end. Then run a 14 gauge copper or brass wire through these holes across the diameter of the pipe and fasten it securely. Have the other end of the tube fitted with a coupling to take three-quarter-inch pipe so that a handle can be attached of any length required.

After the tamping has been taken out of the failed hole with the prospect auger, this tube can be pushed down into the explosive. The explosive will rise in the tube and when this is full the wire will serve both to cut the explosive off as the tube is twisted around and to hold the explosive in place until the tube can be lifted out of the hole and the dynamite removed. Then the tube can be put down again and the process repeated. A little water should be kept in the hole throughout the operation both to soften the charge and to prevent friction which might create sparks.

A post hole auger made of copper and handled carefully has been used with good results for removing explosives from a missed hole.

After enough of the charge has been removed to make firing of the hole safe, a new primer should be put in and the hole tamped. Under these circumstances water is the ideal material for tamping.

Sometimes the charges in the holes adjacent to the hole that fails break the rock to such an extent that the misfire is not discovered until the shovel digs into the bank and uncovers unexploded dynamite. In such a case the steam shovel and all other equipment which might throw sparks or might be damaged by an explosion, and all workmen, should be withdrawn immediately to a safe distance. Then the blaster or some other man who has had experience in handling explosives should carefully remove the broken rock, keeping a sharp lookout for loose explosive, until the bore hole containing the charge that failed is exposed. Circumstances alone can determine whether it will be possible to insert a primer and fire the entire charge, or whether some of it must first be removed before the hole can be fired, or whether the entire charge must be removed from the hole. Whichever course is chosen, the careful procedure described in the preceding paragraphs should be followed.

In case of misfires in holes of smaller diameter than well drill holes, it is generally necessary to remove the tamping in order to insert a new primer to fire the charge. This can be done by the use of a blowpipe and compressed air, or of water pressure, or of copper augers and spoons. The relative advantages and disadvantages of these methods as discussed in the next section apply equally to open work.

If a small diameter hole that misfires is a bench hole that has not been sprung, the best procedure is probably to drill another hole beside it, from one foot to two feet distant, depending upon the depth of the hole, and in such a position that a charge fired in the second hole will break the rock away from the first hole so that the unexploded dynamite can be recovered. A misfire of a sprung hole should never be treated in this way as there would be great danger of drilling into explosive in the chamber or in a crevice made by springing.

MISFIRES IN METAL MINES AND TUNNELS

The classes of work in which misfires occur in the greatest number are metal mining and tunneling. At one time it was considered a more or less standard safety practice in such operations that in case of misfire a second hole should be drilled parallel to the missed hole at a safe distance away, never closer than one foot, and that this should be loaded and fired, with the object of exploding the missed charge by concussion. If there is sufficient burden on the missed hole to make this feasible and if firing the second hole explodes the charge in the first, all is well; or if the shot does not explode the first charge but exposes the unexploded powder so that it can be recovered intact, this disposes of it safely. However, there is such grave danger that unexploded dynamite will be thrown out and scattered amid the broken rock and later struck by a pick or shovel that some important companies have rejected this practice altogether. If the practice is followed, careful search should always be made in the broken material for unexploded dynamite. A second hole should never be drilled alongside a misfired hole that has been chambered or in material where there are seams or crevices.

Today, in underground operations other than coal mines, the common procedure in handling a misfire is to attach a metal blowpipe to the compressed air hose, run the pipe in the hole, blow out the tamping and insert a new primer. This use of compressed air for blowing out tamping involves several dangers. It is practically impossible to know when all the tamping has been blown out and if the primer is at the top of the charge and the blowpipe strikes it hard, the detonator may explode. This can happen whether the pipe be of steel, copper or brass. Moreover, when the charge is a granular explosive, the force of the air is more than likely to spread powder all along the sides of the hole, for the blowpipe is smaller than the hole and it is impossible to stop blowing the moment the charge is reached. In a bore hole coated with dynamite the friction of the pipe as it is run up and down in the hole or the blows which the force of the air causes the pipe to strike against the sides of the hole may easily start a premature explosion. Things that sound far-fetched, perhaps, actually happen with explosives. In one case, powder blown from a hole before the air could be turned off remained on an adjacent slab in sufficient quantity to explode when a workman struck the slab with a sledge and the man lost his eyesight. Instances are also known where some of the powder in a missed hole was blown by the compressed air into a crevice in the rock and later drilled into and exploded.

When the missed hole is charged with gelatin dynamite the dangers of blowing out the tamping with compressed air are decreased, but even then a metal blowpipe introduces a hazard. A substitute is a piece of stiff rubber tubing fitted with a coupling so that it can be attached to the air line and also with a valve for controlling the flow of air. If it is desired to remove the explosive after the tamping has been blown out, this can be done by working the tube around in the hole until the force of the air has loosened up the charge and then gradually withdrawing the tube. The cartridges or chunks of gelatin will follow the tube up the hole and in this way the primer can often be recovered and the cause of the misfire ascertained.

If compressed air is to be used for blowing tamping out, the hole should be kept drenched with water. This is especially important if the charge is a granular explosive and if a metal blowpipe is used. The work should be done only under the supervision of a foreman or shift boss, and the greatest caution should be observed.

In general, however, the safest method of removing tamping from a bore hole, and the one strongly recommended, is washing it out with water under pressure. The tamping usually needs to be loosened up first and for this a tool being successfully used by two large companies is suggested. This is made from a copper rod three-eighths of an inch in diameter and about six feet long. One end is flattened for almost six inches to a width of one inch, and the tip is cut into the shape of a V and sharpened. This end is used for loosening up the tamping preparatory to washing it out with water. The other end is flattened for about fifteen inches to a width of one and one-half inches, this portion is heated and twisted somewhat like an auger and the tip is split like a coal auger and sharpened. This end is used for pulling out the tamping in case there is not sufficient water pressure to wash it out. The tamping is kept thoroughly wet while it is being loosened or pulled out. The companies referred to have standardized on a certain number of inches of tamping for every hole so that the blaster always knows just where the top of his charge is located. With the tool described a blaster can remove twenty inches of tamping in from ten to twenty minutes, depending upon conditions. Of course, ordinary copper augers and spoons may also be used, always, be it remembered, in conjunction with water, for loosening and removing tamping.

There was a time when only compressed air was available in many mines and tunnels, but the modern drills are all equipped for wet drilling and water is now found in almost every working place, and, in many operations, under considerable pressure. Water pressure is a much easier, quicker and safer means of removing tamping from a missed hole and should be used in preference to compressed air whenever possible.

MISFIRES IN COAL MINES

Coal mining is the field in which dangerous practices in handling misfires are most common. Undoubtedly many miners have lost their lives through these practices, but the number of accidents so caused is unrecorded for the reason that the coal miner generally works alone so that there is no witness to the accident and the explosion which kills the miner also destroys the evidence as to the cause which produced it.

When a miner who is shooting with miner's squibs has a shot fail, what he usually does is to push the needle back in the hole again to make a clear path for another squib. This is exceedingly dangerous, for the first squib may have lodged in the hole and may still be burning and the needle may push this burning material down into the powder, thus setting off the blast while the miner is still at the face.

A simple expedient which some experienced miners use when the first squib fails to fire a shot is to stick a pin in the powder end of a fresh squib, insert this in the hole and light it. Oftentimes the pin will penetrate the portion of the first squib which may be clogging the hole and clear the path so that the second squib will dart through to the powder and ignite it.

Of course, the first principle of safety in dealing with any misfire where a miner's squib or safety fuse has been used is to wait a sufficient length of time to avoid all possibility of accident from a delayed explosion. As an illustration, some anthracite mines require a 12-hour wait. This period of waiting is frequently prescribed by the state mine laws or company regulations or by both, but continual vigilance on the part of the mine management is required to see that the men actually observe it.

When the failed hole is primed with blasting cap and fuse, electric blasting cap or electric squib, most miners bore out the tamping and pull out the primer—that is if they do not bore into the detonator and blow themselves up before they have a chance to recover the primer. The exact depth of tamping in a bore hole in coal is rarely known and the miner will probably bore into the explosive before he realizes it. Moreover, with an electric detonator in the hole, the wires are likely to become twisted around the auger and the detonator thus pulled forward so that it may be struck even before the explosive is reached. In fact the hazards of boring out a misfired hole in coal are so great that this practice should be discouraged by every means possible.

In most states the law prescribes boring and loading a new hole and this is the only procedure that can be recommended. In general, it seems best to drill the new hole on the free side of the missed hole, and at least twelve inches away from it. The object of shooting the second hole is to expose the charge in the first hole or blow it out so that it can be recovered. A careful search should always be made in the debris to recover all unexploded powder and particularly the detonator. When the hole has been primed with blasting cap and fuse it is easy to follow the white fuse and find the primer. If an electric blasting cap or electric squib has been used, the wire extending from the hole should be tied to a block of wood or roll of paper before firing the second hole. This is a big assistance in recovering the detonator and locating the unexploded charge.

If the failed hole has been loaded with either black blasting powder or pellet powder, and if open lights are used, great care must be taken to keep the lights back at a safe distance as the failed hole may have spilled a train of powder which, if ignited, would flash back to the main charge with disastrous results to the blaster.

Some mines have a rule that all misfires shall be reported to the mine foreman or the supervisor of blasting and that subsequent steps shall be taken only under his supervision. If this rule could be generally adopted and mine foremen or shooting supervisors were especially instructed on this subject, it would do much to reduce the hazards that now attend the handling of misfires in coal mines.

Miners should be warned against the loading of blasting holes with any kind of explosive while electrically driven machinery (drills, cutting machines, scrapers, locomotives, etc.) are in operation nearby.

It is recommended that where possible holes should be blasted on the day they are loaded and tamped. In some coal mines in intermittent working seasons holes remain loaded and unfired for several days. Under these conditions misfires are very likely to occur.

ORGANIZATION OF OPERATIONS, SELECTION AND EDUCATION OF MEN AND MAINTENANCE OF DISCIPLINE

In addition to all the preceding detail in regard to the safest type of explosives and blasting accessories for quarrying, mining and other blasting operations, and the safest methods of handling them, there remain three fundamental principles for avoiding accidents.

The first of these principles is that the fewer men there are handling explosives, the fewer will be the risks of accident. This means division of labor and systematizing of operations. It means that main magazines and distributing magazines will each have one man in charge, and that no one else will be allowed to receive or issue explosives or detonators. In coal mines it means the employment of shot firers wherever feasible. In quarrying, tunneling and similar operations where a crew of men work together, it means a definite assignment of the several tasks of carrying explosives and detonators, opening cases, loading, priming, tamping, connecting blasting circuits and firing, so that the entire crew will know exactly what each man's duties are and everything will be done in a precise and orderly manner with no unnecessary men about and with no haphazard assumption of the various tasks to be performed.

For instance, if one man must direct the loading of a large well drill blast, probably eight men are as many as he can supervise adequately. A systematic arrangement would be to organize these men into two loading crews of three each and have one crew load all the even holes and the other all the odd holes, while the other two men would open dynamite cases and carry them to the holes one at a time, as needed, and pour the stemming material into each hole as loaded. In each loading crew one man could drop cartridges, one hand them to him from the case and the third take measurements with the tape line and handle the rope when necessary to use the tamping block. Persons other than the loading crew should be kept away from the vicinity of the holes and the dynamite.

The second principle is that the men who do handle explosives should possess certain characteristics and knowledge and experience. They should be picked for intelligence and good sense and they should understand explosives—what they should do with them and what is dangerous—a kind of knowledge that can be gained only by experience. There are many men employed in mining, quarrying and other blasting operations who have the requisite knowledge and good judgment, men who habitually handle explosives with skill and discretion, but others must be constantly trained. An absolutely green man should always be given definite instructions before he is allowed to handle explosives at all, and then should work under the supervision of a careful, experienced man until he demonstrates that he can be relied upon not to endanger himself or his fellow workers. Men who are in the habit of using explosives but who, through ignorance or carelessness or bravado, follow unsafe practices, constitute the greatest problem. If the man is careless to the point of recklessness and unwillingness to mend his ways, the sooner he is removed from all contact with explosives, the safer; but for the training of the others many schemes are in successful use, some adapted to one operation, some to another. Among these are the posting of safety regulations and of large scale, easily grasped illustrations of safe methods at a place where men congregate; the distribution of bulletins—generally most helpful if illustrated—to men who can learn from the printed page; the holding of safety meetings and blasters' schools at regular intervals in which a definite and progressive program of education is carried on through talks by officials or others equipped to give instruction, through motion pictures, and perhaps most important, through question and free discussion among the men themselves, and the direct day-by-day instruction of the man at work by his immediate superior.

One of the most important services given by explosives manufacturers to the consumers of their products is the sending of technically trained field men into every kind of blasting operation to show the men on the work the safest and most efficient blasting practices. The explosives companies, the United States Bureau of Mines and the National Safety Council all issue valuable bulletins describing safe and dangerous practices, but these are necessarily somewhat general. The superintendent and safety engineer can and should go a step farther than this. They should make a periodical survey of the entire operation of which they have charge to ferret out all the hazards that exist under the specific local conditions, and then should devise ways and means to remove the unnecessary hazards and to train the men to avoid accidents from the hazards that can not be eliminated.

The shot firer in coal mines should never be of the bravado type who gambles not only with his life but with the lives of his fellow workmen and with the property of the operating company. This type should not be allowed to handle explosives in mines. In fact, it is recommended that no miner should be allowed to fire shots in a coal mine unless he has a certificate of competency at least as high as that of a fire boss.

The third general principle is that safety regulations must be enforced. Men must not only be taught safe practices but they must be required to use them. This means that close supervision and strict discipline must be maintained—not nagging supervision and harsh discipline, but continuous, friendly and helpful oversight, with impartial application of penalties for violations of rules and quick recognition, with or without appropriate awards, of care in observing them. Much can be accomplished by fostering among the men a group spirit of responsibility for safety and by encouraging friendly competition between individuals and between groups for the reduction of accidents.

DON'TS

1. Don't store blasting caps, electric blasting caps, high explosives or blasting powder in a residence, home, boarding house or any other human habitation, or leave them lying around where children can get them.

2. Don't leave explosives in a wet or damp place. They should be kept where it is clean, cool, dry and well ventilated.

3. Don't leave explosives in a field or any place where stock can get at them. Cattle like the taste of salts in explosives, but these or other ingredients will probably make them sick or kill them.

4. Don't store explosives so that the cartridges stand on end.

5. Don't store explosives in or near a blacksmith shop, or near a stove.

6. Don't open cases of explosives in a magazine.

7. Don't throw packages of explosives violently down or slide them along floors or over each other or handle them roughly in any manner.

8. Don't smoke while using or handling any explosives.

9. Don't handle explosives near open lights, other fire or flame, or sparks.

10. Don't have matches about you while handling explosives. Where matches are used to light the fuse, they should be contained in a closed metal box.

11. Don't use any tool other than wooden wedges and wooden, fibre or rubber mallets for opening cases containing high explosives.

12. Don't use blasting powder with permissible explosives or dynamite, nor dynamite with permissible explosives, in the same bore hole in coal mines.

13. Don't explode a charge to spring or chamber a bore hole and then load another charge into it before it has cooled sufficiently.

14. Don't force a cartridge of high explosives, especially a primer, into a bore hole.

15. Don't spring a hole adjacent to a loaded hole.

16. Don't tamp with iron or steel bars or tools. Use only a wooden stick with no exposed metal parts.

17. Don't allow explosives, or drill holes while being loaded with explosives, to be exposed to sparks that might come from steam shovels or locomotives in operation, or from any other source.

18. Don't prime both ends of a cartridge of explosive when making primers of half cartridges with a blasting cap or electric blasting cap, before cutting it in two. Cut the cartridge in half and prime each piece separately.

19. Don't shoot into explosives with any firearm.

20. Don't use damaged leading or connecting wire in blasting circuits.

21. Don't connect up or load bore holes for electric firing during the approach or progress of a thunderstorm, and if charges are already loaded and connected, all persons should be kept at a safe distance from them while the storm is in progress. If necessary to leave over night, ends of the wires should be twisted together, coiled and covered with dirt.

22. Don't fire a blast before all persons are at a safe distance or under sufficient cover, and all explosives are in a safe place.

23. Don't allow occupied automobiles near the danger area of the blast.

24. Don't attempt to investigate a misfire too soon, even though it is thought the fuse has not been lighted or has gone out.

25. Don't drill, bore or pick out a charge of explosives that has misfired. Where required by law, drill and charge another bore hole at least two feet from the missed one. If this is done, make careful search for unexploded material in the debris.

In some cases, as in well drill, sprung or block holes, it is often advisable to carefully remove the stemming or make a hole through it to within a safe distance of the charge of explosive, then reprime and explode the charge. In general, misfires should be handled only by a competent and experienced man and the method employed should be in accordance with his best judgment.

26. Don't keep blasting caps or electric blasting caps in the same box, container or magazine with other explosives.

27. Don't leave packages of explosives or blasting caps uncovered.

28. Don't leave high explosives, blasting caps or electric blasting caps exposed to the direct rays of the sun.

29. Don't store or carry blasting caps or electric blasting caps with any other kind of high explosives.

30. Don't allow priming (placing of a detonator in the dynamite cartridge) to be done in a magazine.

31. Don't have electric wires or cables, which may be carrying current, near blasting caps or electric blasting caps, explosives or charged bore holes at any time except for the purpose of firing the blast.

32. Don't use any blasting caps—or electric blasting caps, weaker than No. 6.

33. Don't attempt to use electric blasting caps with plain wire and normal insulation in very wet work. For this purpose use waterproof electric blasting caps having enameled wires.

34. Don't use electric blasting caps or other electric firing devices of different manufacture in the same circuit.

35. Don't attempt to take blasting caps from a box by inserting a wire, nail or other sharp instrument.

36. Don't attempt to remove or investigate the contents of a blasting cap or electric blasting cap.

37. Don't carry blasting caps or electric blasting caps in pockets of clothing.

38. Don't try to withdraw the wires from an electric blasting cap.

39. Don't tap or otherwise investigate blasting caps or electric blasting caps.

40. Don't spare force or energy in operating blasting machines.

41. Don't store fuse in a hot place as this may injure the fuse and cause the waterproofing material to damage the powder train.

42. Don't handle fuse carelessly in cold weather. When cold it is stiff and breaks easily. It should be warmed slightly before using. Avoid kinks in fuse and wires.

43. Don't use short fuse. Cut fuse sufficiently long to extend beyond the collar of the hole and sufficiently long for safety in retiring from the blast. Never use less than two feet.

44. Don't cut fuse on a slant, but cut it square across. Cut off an inch or two of fuse to insure having fresh end inserted in the blasting cap, and see that the fuse is seated against the detonating agent in the cap.

45. Don't crimp blasting caps to fuse with a knife blade or with the teeth, but see that the blasting cap is securely attached to the fuse by means of a suitable cap crimper.

46. Don't lace fuse through cartridges of explosives. This practice is frequently responsible for the burning of the charge, or misfires in wet work.

47. Don't hold the primer cartridge in the hand when lighting fuse.

48. Don't light fuse in any bore hole or where the explosive charge in the hole or in adjacent holes has not been covered with sufficient stemming material to protect the explosives from sparks from the end spit of fuse or a flying match head.

49. Don't try to light fuse with burning paper, other inflammable refuse or improvised torches.

50. Don't use empty dynamite boxes for kindling.